ELECTROMECHANICAL
components & systems DESIGN
SEPTEMBER 1961

SEP -6 1961

in this issue

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Transistor and Diode Testing

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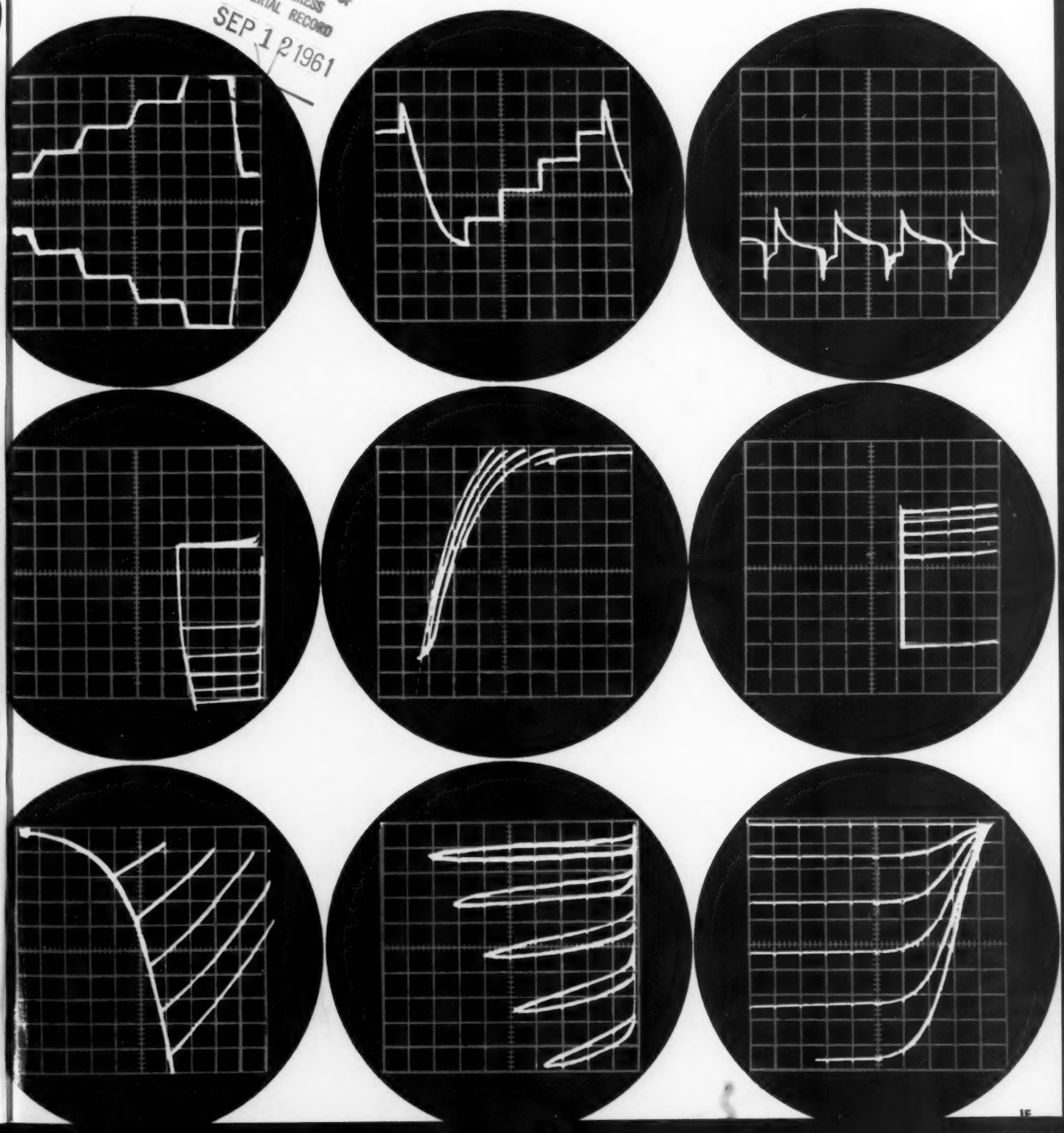

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New design features in Librascope encoders have sharply reduced noise and eliminated ambiguity, while adding many hours of usable life. Among other features: faster operating and slewing speeds, accuracy you can depend on. And Librascope encoders have proved reliable in more than 15,000 military and commercial installations. Librascope now builds 132 encoder models with a variety of capacities, output codes and case sizes. It's probable that one of these encoders will satisfy *your* shaft position-to-digital conversion requirements. For the details, tell Librascope's engineers your applications and requirements. They'll promptly recommend the best encoder for the job. Just write to Applications Engineering, Librascope, Glendale 1, California. *In a hurry? TWX us collect at BRB 9884.*

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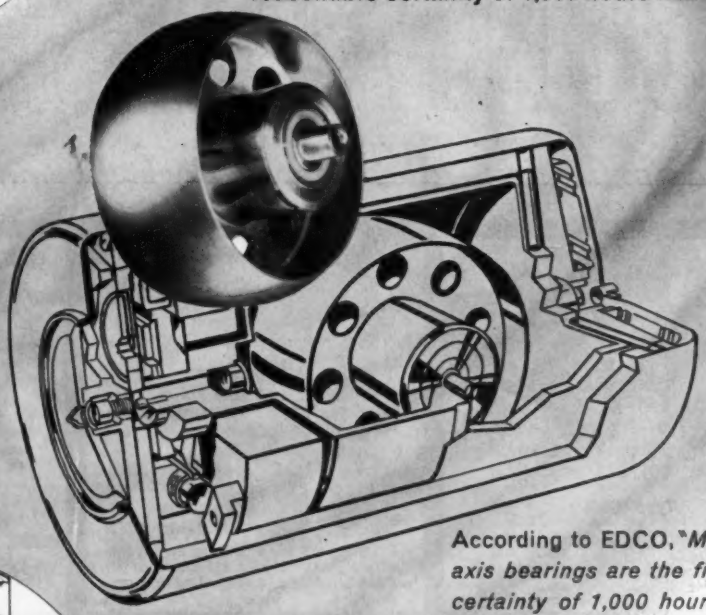
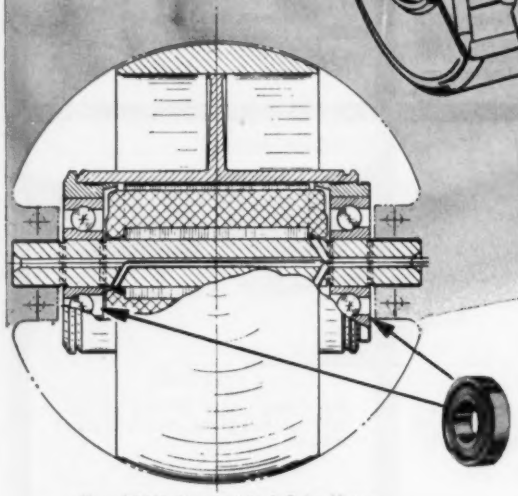
CIRCLE NO. 1 ON INQUIRY CARD

MARLIN-ROCKWELL RELIABILITY COUNTS

with "Gyro" quality instrument bearings in EDCO spin motors . . .

MRC "Gyro" quality spin axis bearings are the first to provide reasonable certainty of 1,000 hours minimum life "as received".





New EDCO Symmetrical Spin Motor
Using the MRC R-3 Size Bearings

According to EDCO, *"MRC 'Gyro' quality spin axis bearings are the first to provide reasonable certainty of 1,000 hours minimum life 'as received', in ultra-precision 'floated' gyros with marginal oil lubrication at 200° F. continuous operating temperature, and at 24,000 RPM under 2 lb. preload."*

One of the critical problems in the development of missiles was the creation of dependable instrument bearings for gyro spin motors.

There were two main obstacles to consistent low torque and long life for gyro spin axis bearings. One was the polymerization of the lubricant and the other, close control of retainer porosity. The special MRC processing which solved both of these problems is now standard practice with all MRC bearings for spin motor applications. Their continued success in actual operation is graphic testimony to the effectiveness of this program.

MRC "Gyro" quality bearings are practically 100% free of the sub-micro particle contamination found in most bearing raceways. The retainers are specially treated and deburred and have a controlled guaranteed oil absorption up to 8% dry weight of the container, depending on the size and requirement of the application.

Consult OUR Engineering Department on YOUR Bearing Problems

MRC
BALL AND ROLLER *bearings*

MARLIN-ROCKWELL CORPORATION

Executive Offices: **Jamestown, N. Y.**

CIRCLE NO. 2 ON INQUIRY CARD

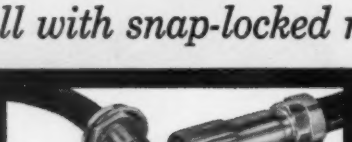
COAX HYFEN® CONTACTS

reliable solderless contacts result in dramatic reduction of installation time

wide application—all with snap-locked removable contacts

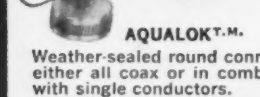
Type MB-X

Coax in miniature rectangular configurations.



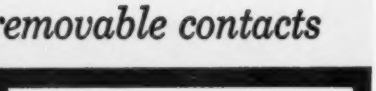
AQUALOKT.M.

Weather-sealed round connector—either all coax or in combination with single conductors.



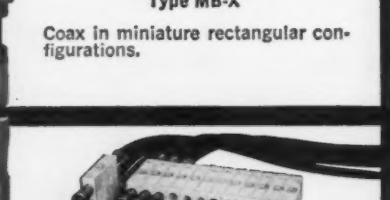
Coax Bantam HYFEN

Connectors for standard and miniature coax—either all coax or in combination with single conductors.



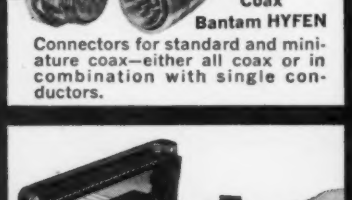
Coax Feed-Thru

Miniature and standard connector (above) and splice (below). All plastic shells — lightweight, durable, impact resistant.



Coax MODULOK®

Modular terminal block with spring-loaded removable contacts.



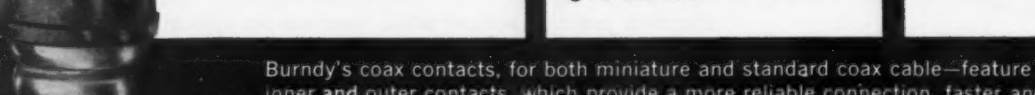
Type PD-X

Modular HYFEN inserts for all standard or miniature coax or in combination with inserts for single conductors.

Type ME-X

Rack and panel HYFEN series—features one piece shell, one piece inserts.

Burndy's coax contacts, for both miniature and standard coax cable—feature crimped inner and outer contacts, which provide a more reliable connection, faster and easier. High speed production tooling results in low installed cost—crimps contacts in any circumferential position. Few parts simplify installation. No heat to damage insulation.



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CIRCLE NO. 3 ON INQUIRY CARD

ELECTROMECHANICAL components & systems DESIGN

The Sourcebook of Design Ideas in Applied Electromechanics

SEPTEMBER 1961 • VOL. 5 NO. 9

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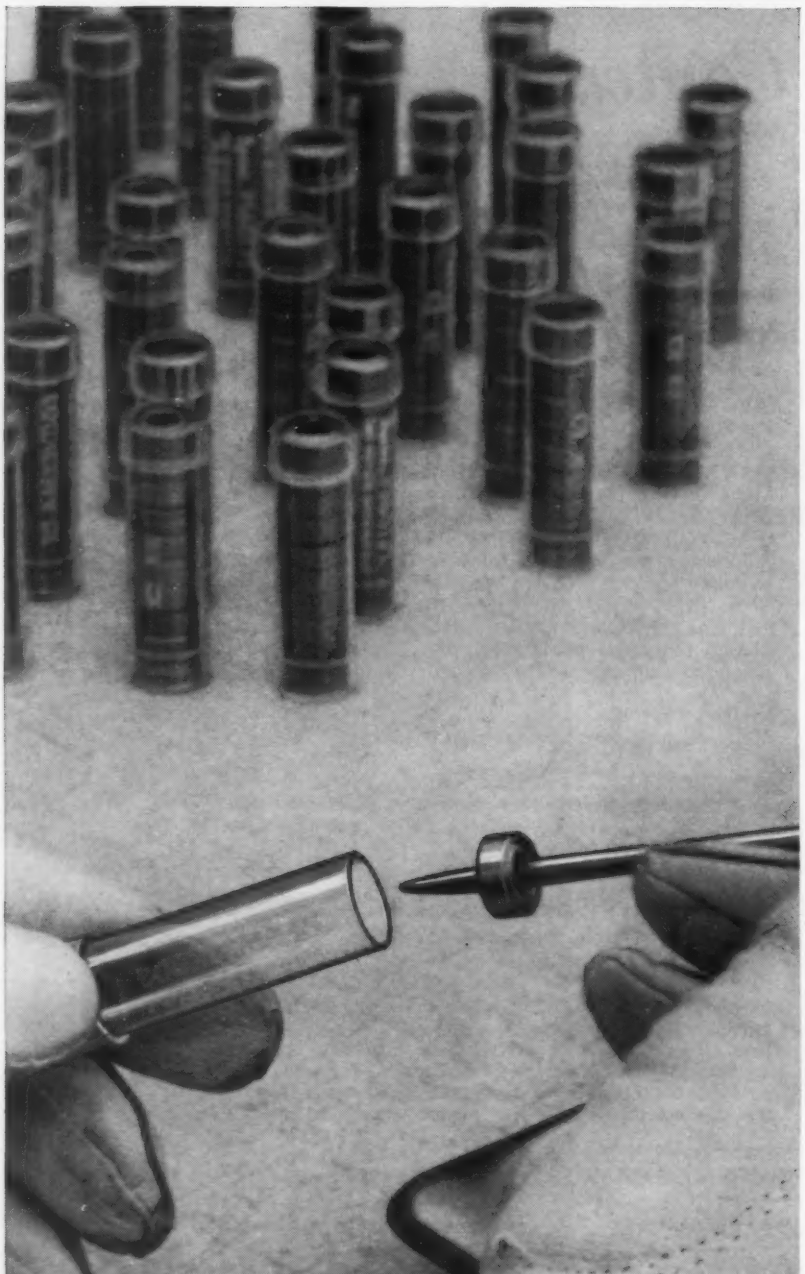

for these six important high performance features in miniature ball bearings

1. Centerless Honed Raceways — The only miniature ball bearings with honed inner and outer races. Noise and vibration reduced to new, low levels.

2. Vacuum-melt Extra-Clean 440C Stainless Steel — No pits or imperfections in balls, raceways. Provides better finish, super-sensitive performance, low torque values.

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4. Hardened Retainers — Hardened 410 stainless steel retainers maintain proper and accurate form when assembled. No distortion. Retainer prongs remain springy, prevent permanent bend.

5. Heat Stabilization — Stabilized to 600°F. Standard Fafnir Miniature Ball Bearings take high temperatures.

6. Precise Tolerances — Bore, O.D., and internal geometry held to precise tolerances to meet the most exacting customer requirements.

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This stamp on a Fafnir Ball Bearing means finest quality and workmanship . . . dependable supply . . . competent engineering help . . . and **responsibility** in meeting your bearing needs. It's worth bearing in mind.

FAFNIR
BALL BEARINGS

CIRCLE NO. 4 ON INQUIRY CARD

ELECTROMECHANICAL
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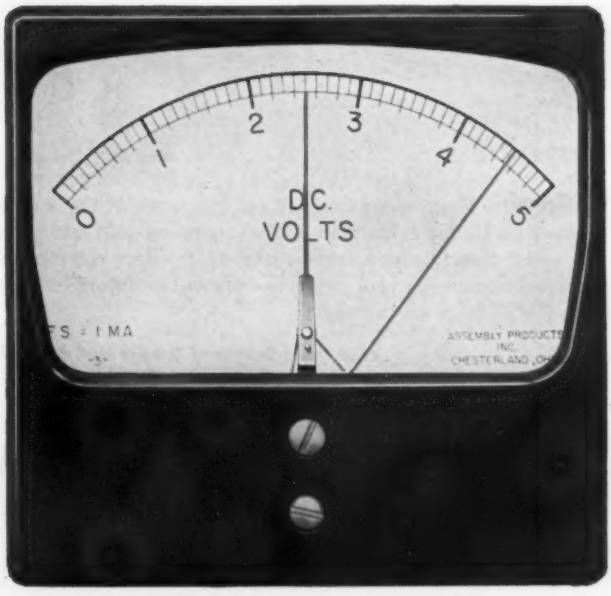


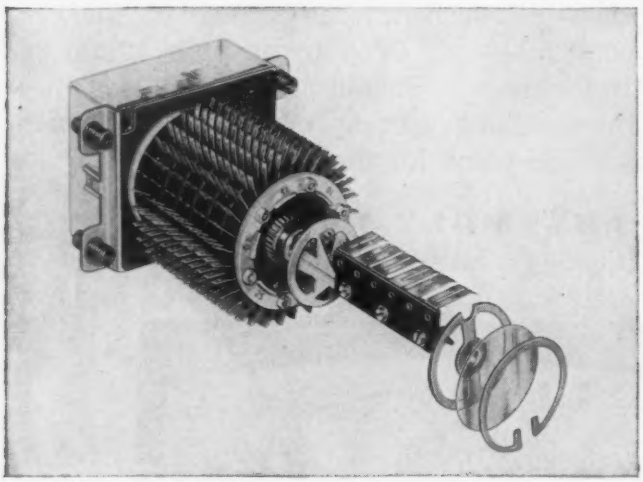
SA 2376

CIRCLE NO. 5 ON INQUIRY CARD

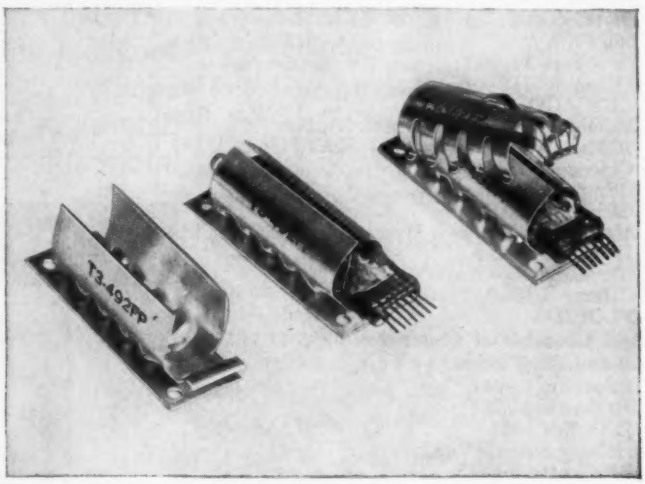
2 WAYS

(AND THEN SOME) HANDY & HARMAN CAN HELP YOU WITH ELECTRONICS APPLICATIONS

...Take Rotary Stepping Switches—The single wiper for this rotary stepping switch is made of Handy & Harman Consil 995. This silver-magnesium-nickel alloy possesses extremely high thermal and electrical conductivity and retains its spring properties and excellent conductivity even at high ambient temperatures. The bank contacts are silver plated from Handy & Harman anodes—available in a range of finenesses including the standard 999+ fine. Switch components courtesy of North Electric Company, Galion, Ohio



...Take Heat Dissipating Tube Shields—Handy & Harman Consil 995B and Fine Silver are helping to meet the critical problems of vibration and heat in subminiature tubes. The shield assembly makes use of pure silver which, being extremely soft, conforms to tube irregularities and conducts heat away with an efficiency unmatched by any other commercially produced metal. The shield base, or heat sink, is made of Consil because of the alloy's excellent thermal conductivity and ability to stay rigid at elevated temperatures. The Consil and Fine Silver are joined with EASY-FLO, a Handy & Harman silver brazing alloy. Photo courtesy of International Electronic Research Corporation, Burbank, California.



...And Then Some—These two examples are indicative of the ways in which the electronics and electrical industries are solving their problems with Handy & Harman precious metals: gold and silver and their alloys in wire, strip and foil; silver powders, flake and paint; silver chlorides and oxides; bi-metals; silver sintered metals; anodes, etc. The "etc." is our invitation to you to contact us in reference to any of your projects—present or future—that may involve the use of precious metals. We'll be glad to advise you, without obligation on your part.

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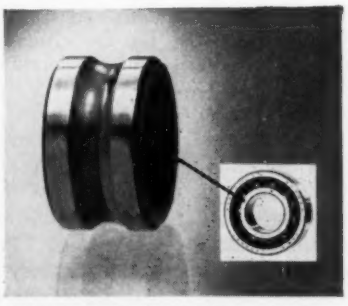
CIRCLE NO. 6 ON INQUIRY CARD

A NEW PRODUCT DEVELOPMENT FROM BARDEN

PERFORMING WELL IN A HOT SPOT

As every parent knows, small boys have an amazing capacity to perform well in heat that would fell the average adult. In much the same way, BarTemp* ball bearings operate effectively up to 575° F., permitting synchros, fans, control motors and other lightly loaded devices to perform at higher temperatures than ever before.

*TRADE MARK



▲ Unretouched photo of inner ring from BarTemp bearing that ran 2727 hours—1010 hours at 500°F. plus an additional 1717 hours at 575°F. Dark band in raceway is lubricant transferred from retainer.
▼ Excerpts from lab and field test results.

Bearing	Temperature	Speed (RPM)	Hours
SR3HX110	500°F. 575°F.	1,200	2727
SR4HX110	338°F.	10,000	2500+
SR3HX110	392°F.	1,200	1240+
SR3BSSX112	500°F.	4,500	1036+
SR2HX110	575°F.	2,500	1628

NEW DESIGN DEVELOPMENTS

Two design innovations made BarTemp possible—a Barden-developed heat treatment for stainless steel used for the bearing rings, and a new retainer that serves as a dry lubricant and a ball separator. The BarTemp retainer, reinforced Teflon compounded with a solid lubricant, is the sole lubrication required. As the bearing rotates, the balls transfer microscopic particles of the lubricant to the raceways.

TEST RESULTS

In tests by more than 20 precision bearing users, BarTemp bearings in synchros, control motors, blowers, pressure switches, tachometer generators and other lightly loaded devices have operated from 1000 to 24,000 RPM and at temperatures from −100°F. to 575°F. Typical life exceeds 1,000 hours.

PROTOTYPES AVAILABLE

Prototype quantities of seven BarTemp sizes from .3125" to .7874" O.D. are immediately available in angular contact types, open or shielded. For further data and detailed test results, ask for BarTemp Data Sheet B-1.

Barden is a major supplier of miniature, instrument, spindle and turbine bearings volume-produced to ABEC 7 tolerances or better

for reliability...specify

BARDEN PRECISION BALL BEARINGS

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CIRCLE NO. 7 ON INQUIRY CARD

MINIATURE SILICON DIODES DISSIPATE 10-WATT OVERLOADS WITHOUT FAILURE

Bonding the diffused silicon wafer directly between terminal pins and fusing a hard glass sleeve to all exposed silicon surfaces and the terminal pins permanently stabilizes electrical characteristics.

Long-term reliability of glass and top-hat diodes has been a two-fold problem.

- Surges, even though small, cause catastrophic failure.
- Electrical characteristics change radically with aging or exposure to environmental extremes.

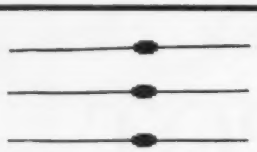

Fig 1 Actual size of Unitrode silicon diodes. They are ¼ the size of conventional glass diodes and 1/50 that of top-hat rectifier.

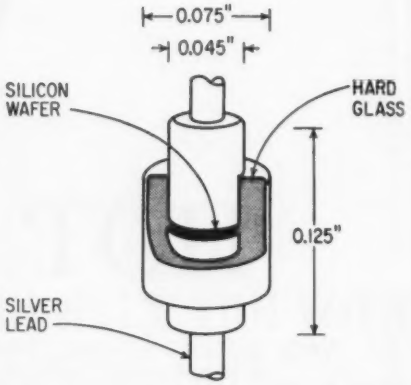

Fig 2 Cut-away drawing of the Unitrode silicon diode shows the high-dielectric glass (cross-hatched area) fused to the surface of both the silicon and terminal pins. This construction, eliminating the "whisker" spring, assures long-term stability in severe military environments even with extreme continuous overloads, provides significantly higher power ratings and temperature range, and makes the diode unaffected by shock, vibration and acceleration.

SURGE FAILURES

The ohmic contact to the semiconductor has been an extremely fragile "whisker" or spring, which fails for mechanical or electrical reasons. Mechanical vulnerability of a fine diameter wire spring exposed to heat, vibration, shock, or acceleration is unavoidable. Even more important is failure of the spring when exposed to electrical overloads barely exceeding the diode rating. Failure occurs, usually, at the point where the spring contacts the semiconductor material, and is due to burnout caused by local heating, which melts contact alloys.

LONG-TERM CHANGES

Within the glass envelope of the diode, the semiconductor material is ordinarily left exposed to gas or partial vacuum. The critical area is the section where the P-N junction extends through the material. With normal power, aging, temperature change, etc., it is impossible to prevent addition, subtraction, ionization or migration of surface contamination. This is a problem inherent in all uses of hyper-clean surfaces. Such surfaces have widely varying electrical characteristics with the addition of only a few molecular layers of nearly any type of absorbed ion and atom. Kingston, et al., have written a book on this subject. In general, the effect is manifested by surface leakage changes, which show up as increases in diode leakage and a rounding of the knee of the reverse voltage current curve.

Surfaces of germanium or silicon become coated with thin layers of oxide upon exposure to air. In the presence of only very minute quantities of oxygen, at least a monolayer is formed. Thin layers of the dioxides are extremely hygroscopic exhibiting the same characteristics as silica gel. Application of organic varnishes and controlled oxidation of the silicon surface have made possible the relatively consistent reverse characteristics of present-day diodes as shipped

PARTIAL TABLE OF CHARACTERISTICS

Unitrode Type Numbers	EIA (JEDEC) Equivalents	P.I.V.'s	Maximum Reverse Current @ PIV @ 25°C	Maximum Average Forward Current @ 150°C	Maximum Average Forward Current @ 25°C
UT211 to UT215	IN645 to IN649	225-600V	0.2 ua	250 ma.	750 ma.
UT221 to UT233	IN676 to IN689	100-600V	1.0 ua	150 ma. 250 ma.	500 ma. 750 ma.
UT111 to UT118	IN536 to IN1096	50-600V	10.0 ua	250 ma.	750 ma.
UT21 to UT27	IN482 to IN488	30-380V	0.25 ua	100 ma.	300 ma.
UT11 to UT14 UT15 to UT18	IN461 to IN464 IN461A to IN464A	25-175V	0.5 ua	50-120 ma.	150-400 ma.
UT252 to UT258		200-800V	10.0 ua	1000 ma.	2000 ma.
UT262 to UT268		200-800V	10.0 ua	1500 ma.	3000 ma.

Operating temperature range: −100°C to +250°C. Storage temperature range: −195°C to +300°C
Power dissipation: 1.0 to 4.0 watts

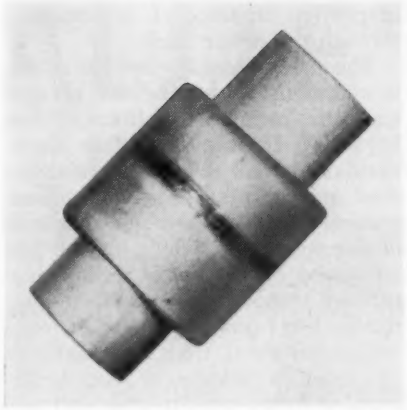

Fig 3 Photomicrograph showing silicon dice bonded between terminal pins and surrounded by hard glass. Center section, including the silicon and half the pins is magnified by the glass.

from semiconductor plants, but have not produced the stable surfaces in the inert environments that will yield unchanging characteristics with ageing, overloading, and exposure to thermal and mechanical extremes.

WHISKERLESS CONSTRUCTION

An improved packaging concept by Unitrode Transistor Products, Inc., Waltham, Mass. has eliminated the "whisker" spring and placed the only exposed surface of the silicon in an ambient of inert hard glass. The package permits continuous overloads to a minimum of 10 watts with no failure and assures long-term stability in severe military environment. The Unitrode can be dip-soldered and subjected to thermal shocks between −195°C and +300°C and is unaffected by mechanical shock, vibration and acceleration.

Construction of the diode is shown in Fig 2. Leads, terminal pins, and the diffused silicon wafer are bonded together into a single assembly. The glass bead completely covers the portion of the diode sensitive to environment. The glass is in intimate contact with the silicon and the pins, leaving no void in which gas, air or other contaminants could accumulate. Since the hard-glass ambient cannot contaminate the silicon surface, the surface is permanently stabilized. Electrical characteristics of the diode are fixed and independent of overloads and environmental changes.

A high power dissipation safety factor is provided by the two terminal pins, which are fused to both sides of the silicon wafer. The metal pins have the same diameter as the wafer and therefore conduct heat away from the silicon and into the silver leads at a rapid rate. This construction is in contrast to that of conventional diodes, where the "whisker" spring is bonded to a small area on one side of the wafer.

All materials, including the silicon and the bonds between materials, stand up well at plus 500°, compared with the 150-200°C top temperature of other diodes.

Since the glass and the terminal pin metal have been carefully matched to the same thermal coefficient of expansion as the silicon, fabrication of the diode produces an unstressed structure. Because this common coefficient is low, no ill effects are experienced in wide range temperature cycling, thermal shock or other heat and cold testing. No special precautions are necessary for either iron or dip-soldering assembly procedures.

Unitrode construction is easily adapted to miniature special assemblies. A typical ¼ amp, 800 volt bridge measures 0.33 by 0.25 by 0.15 inches; and a 5000 volt, 200 ma stack, only 3/16 inch diameter, one inch long. No equalizing resistors or capacitors are necessary.

Although Unitrode Transistor Products, Inc. is presently developing many additional types of diodes, rectifiers, and transistors using the new construction, 40 general purpose types of silicon diodes, as listed in the table, are presently in production as stock items at competitive prices. Direct electrical equivalents to all general purpose EIA, JAN, and MIL diodes are available for substitution without change in the circuit boards and chassis.

Other projections are for the introduction of Zener diode types, higher power rectifiers, and several transistor types. At least one of these categories will be available before 1962.

Presently in final stages of development is a line of single diodes with PIV's up to 10,000 volts. These diodes will be somewhat longer than the dimensions shown in Fig 2, but will retain the same diameter. Increase in length will result from increasing the length of glass between the two terminal pins to prevent voltage breakdown in the atmosphere outside the package. Extremely high peak inverse voltages are made possible by complete glass sealing. This seal isolates the terminal pins from each other and fills all the space surrounding the silicon. Silicon junctions are inherently capable of withstanding thousands of volts. Present-day devices do not realize these voltages principally because of shortcomings in the ambient medium surrounding the silicon. With all gas and voids excluded from the package, the high dielectric constant glass of the Unitrode now makes 10,000 volt PIV's an actuality.

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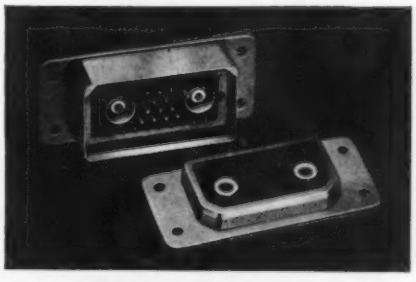

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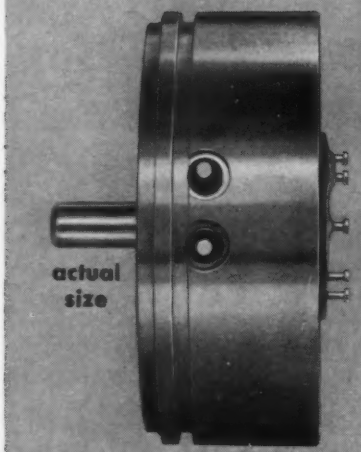

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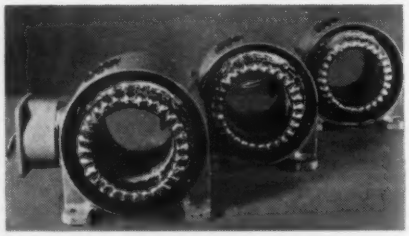

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Developed by the Epoxylite Corp. of South El Monte, Calif., the new encapsulated random-wound motor is fabricated with the aid of adjustable metal molds which contain the encapsulant during cure. In addition, impermeable-metallic barriers encase the windings through the cell section to prevent entrance of contaminants through the motor stack.

The new patent applied-for design is accomplished by the use of non-magnetic metal foil fabricated into adjustable coil molds. Either aluminum, or for very severe duty, stainless steel may be used. Molds which remain in place on the motor after cure of the epoxy are tightly bonded and reinforced by the epoxy resin encapsulating compound. The effect is as though the windings themselves were encased in metal, from the standpoint of chemical resistance; the tough, resilient epoxy casting compound provides the backup strength which is lacking in the thin gauge metal when unsupported. The envelope of metal and epoxy is practically indestructible. All seams are bonded and sealed with a special epoxy adhesive of enhanced chemical resistance.

Because the molds are flexible and easily contoured to the exact configuration of the windings (being separated from them only by the thickness of glass cloth spacing), the amount of encapsulant is minimized and the buildup of the epoxy over the end-turns is ¼" less. Heat generated during operation quickly dissipates to the airstream resulting in cooler operation.

Molds are supplied in a corrugated form to permit ready adjustability to motors of all sizes. The form is placed over the windings, overlapped until the desired fit is obtained, and then trimmed to size with scissors. Such molds are readily adaptable for use by motor repair shops. Completely preformed molds may be employed for the production encapsulation of one-size motors, since low cost tooling can be used for fabrication.

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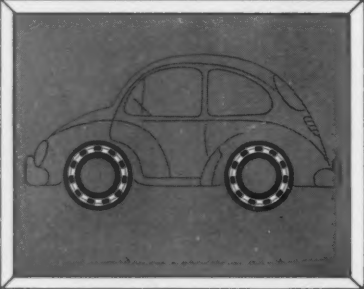

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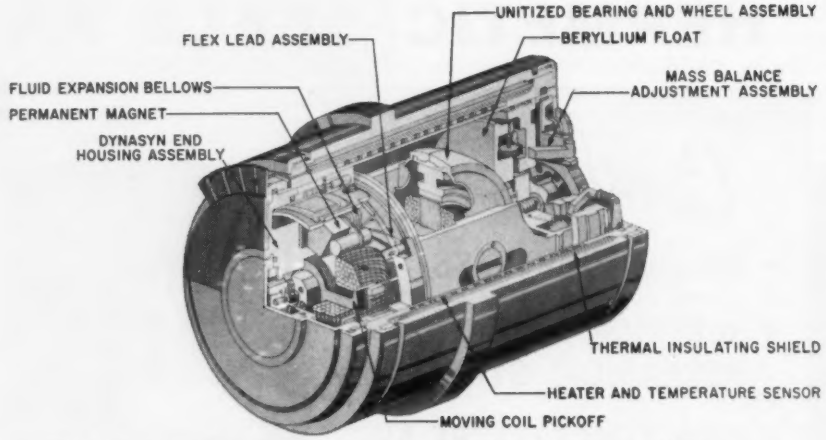

Fig 1 Cutaway drawing of Sperry Gyroscope's diminutive stabilizing gyro.

INERTIAL GUIDANCE

Drift Sensitivity of Miniature Gyro Less Than 0.005°/hr

"If employed aboard a vehicle on a mission to the moon, the gyro's performance would enable the vehicle to land within one mile of the predicted site" – in these words, scientists at Sperry Gyroscope Co. described the performance of their SYG-1000 floated integrating miniature gyro. Weighing less than a pound and under three inches in length, the new gyro has shown drift sensitivity to be less than 0.005 degrees per hour/g^2 under vibration tests involving gravity forces multiplied up to 20 times. Random drift cogging tests show a standard deviation in azimuth position of 0.007 degrees per hour and in vertical position of 0.005 degrees per hour. Thus, the SYG-1000 gyro, if allowed to drift freely over the face of a clock, would take almost 10 years to make one complete turn.

An unprecedented life expectancy has been designed into the gyro through the development and application of new, low-wear ball bearing steels and lubrication practices. An unusual wheel design, which is unitized to the bearing assembly, yields a high degree of geometric control previously unattainable without a complex final assembly operation. A ceramic "Dynasyn" torquer-pickoff, combining both torque and signal generators in a single package, offers high accuracy and a more dimensionally stable geometric form than the separate and bulkier elements formerly used, Sperry said.

Even in rapidly changing aerial and space environments, the unit shows a fast and perpetual readiness. The tiny gyro's non-freezing "Gyrolube" flotation fluid allows safe storage from –85°F to 185°F and quick operation from temperatures as low as –65°F. Thermal averaging layers in the gyro's outer wall provide freedom from temperature fluctuations, even in rapidly changing environments which customarily cause high drift uncertainties.

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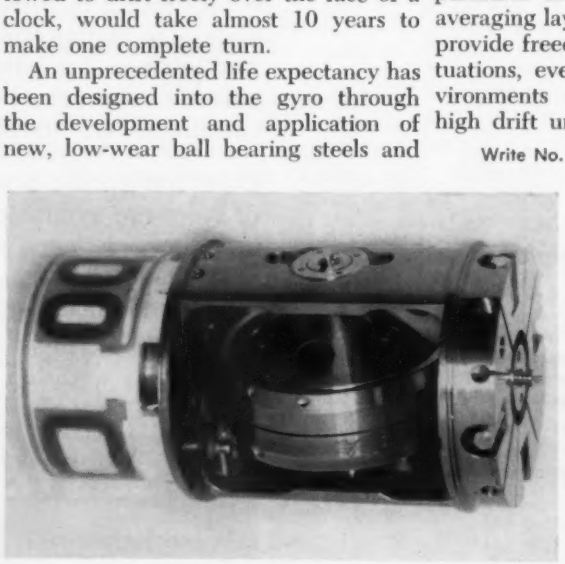

Fig 2 Unique wheel and gimbal assembly is the heart of Sperry's SYG-1000 floated integrating miniature gyro. Gyro wheel is unitized with the bearing assembly and yields a high degree of geometric control. Ultrastable "Dynasyn" torquer-pickoff is at right of bearing assembly.

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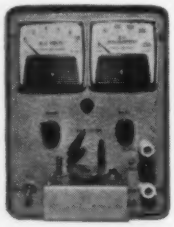

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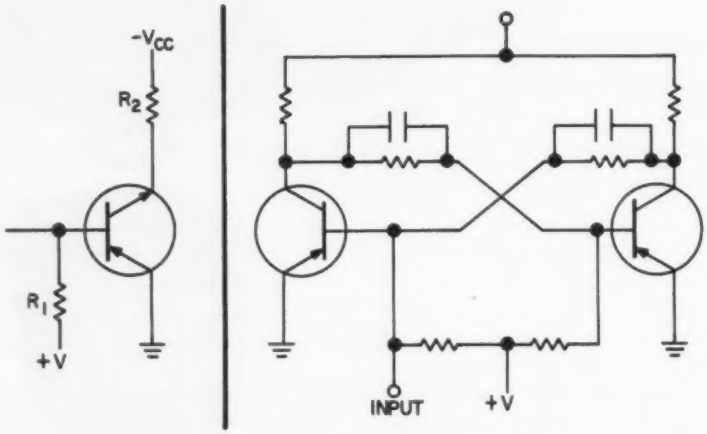

DYNAQUAD FLIP-FLOP CONVENTIONAL FLIP-FLOP

Typical of the kind of simplification that is possible with the Dynaquad is this flip-flop circuit. Here one Dynaquad replaces seven components in the conventional transistor flip-flop circuit. When a negative pulse is applied to the Dynaquad base, the unit turns on and the output rises from —Vcc to zero volts. Positive pulse, applied to the base, turns the unit off, changing the output from zero volts to —Vcc.

What is claimed to be the first alloyed junction, four layer device has been introduced by Tung-Sol Electric Inc. Made possible by a new manufacturing technique, the semiconductor, called the Dynaquad, is a naturál switch with both turn-on and turn-off control at the base. According to the company, it is significantly lower in cost than comparable components. Tung-Sol's new technique of forming multiple junctions with the same simplicity and reproducibility as single alloy junctions accounts for the low cost.

Dynaquad is a germanium, three terminal, PNPN structure packaged in a standard TO-5 case. Capacities and speeds are those usually associated with digital computers. It switches in the megacycle range, with rise times of the order of 0.1 usec and it can provide an output voltage swing of 35 volts. Because of its binary nature, a single Dynaquad can replace a number of transistors and associated components in many applications, and in simple on-off switching it behaves as a pulse operated latching relay with no bounce, chatter or sticking contacts.

During normal operation, applying a small negative pulse to the base turns the unit on and it will remain on after the signal is removed. Turn-off is accomplished by a positive pulse to the base, or by dropping the collector current below the sustaining point.

Because of Dynaquad efficiency in computer applications or wherever digital techniques are employed, Tung-Sol believes that flip-flops, counters, shift-registers and various forms of logic elements can be constructed with a savings of one-third to one-half in components, labor and space. High gain and sharp rise time give the device great utility as a driver. It can accept small or smeared signals and convert them into sizeable current pulses sufficient to drive magnetic cores, relays and thyratrons. A single Dynaquad operates in the three basic multivibrator modes—monostable, bistable and astable.

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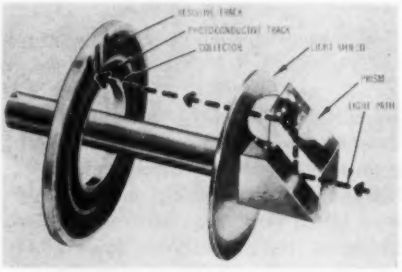
Light beam is directed from source (not shown) along axial path to prism on potentiometer shaft. Beam, deflected radially by prism, strikes annular photoconductive track at point determined by angular shaft position. High conduction set up at the point light strikes photoconductive semiconductor completes circuit between collector and resistive track. Light-to-dark conductivity ratios of customarily used CdS or CdSe range from 10^6 to 10^8:1.

To date, several Betapot versions have been developed which provide both high and low resistive range values. Development of the device was achieved by Duncan Electronics of Costa Mesa, Calif., in cooperation



with Electro Radiation, Inc., Santa Monica, Calif. Current investigations are directed toward use of radioluminescent light sources, such as beta emitting isotopes that require no external power.

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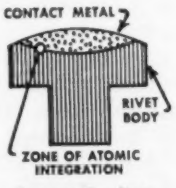

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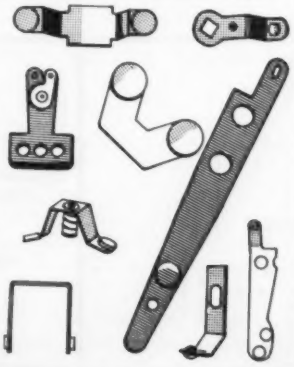

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CAPACITOR COUPLING TRANSISTOR OUTPUT STAGES

Solution of two problems exploits advantages of capacitor coupling in transistor circuits

Mike Bodnar
— Project Engineer, Diehl Mfg. Co.

Marty Glasberg
— Contributing Editor

Capacitor coupling has been used commonly in vacuum tube circuits. This practice has naturally been extended to transistor circuits. Capacitor coupling is small, economical and has a wide frequency range. These advantages are useful in a compact, efficient servo amplifier, particularly at 60 cps where large transformers would be required. At medium power levels, capacitor coupling can be shown to be superior in size to transformers for comparable performance.

A disadvantage of capacitor coupling is that capacitance decreases at low temperatures and has a very definite high temperature limit. Electrolytic capacitors are commonly rated up to 85°C tantalum to ±125°C, and will decrease capacitance by about 50% at −40°C. A transformer has considerably wider temperature ratings. Another disadvantage is that capacitor coupling is not as efficient as transformer coupling. In transformer coupling, all the driver current flows through the transformer, which means that all the ac signal is coupled with only transformer losses. In capacitor coupling, the ac driver current is split between the capacitor coupled load and the driver's load resistor. Also this ac signal is again divided between the coupling capacitor and the impedance of the output transistor.

Although these disadvantages are out-weighed by the advantages, a number of design problems have generally confined use of capacitor coupling to low power Class A stages in transistor circuits. These problems must be considered before the advantages can be fully realized.

PROBLEMS

Vacuum tube circuits hardly ever draw grid current. This means that the input grid impedance is extremely high. Therefore, the loss and phase shift through the typical RC coupler is dependent primarily upon the value of R and C. The R, of course, is the external grid leak resistor.

Transistor circuits, on the other hand, always draw base current. This means that the input base to emitter impedance is rather low. Therefore, attenuation and phase shift through the capacitor coupling must take into account the input impedance of the transistor. It also means that current will flow through the coupling capacitor, changing the bias level, especially in Class B operation. Class B output stages, however, are very desirable because low dissipation (high efficiency) and the resulting low temperature are required in transistor amplifiers. A Class B output stage requires two transistors in push-pull where only one transistor is operating at a time. The theoretical efficiency of this stage is 78%, as opposed to the theoretical efficiency of 50% for a Class A push-pull output. In Class B, however, the transistor is only sensitive to signals of one polarity, that is, it is biased to almost no conduction. This means that the transistor only draws current from the driver in one direction. Therefore, if a capacitor is used to couple the output transistor and the driver, it will charge and consequently tend to block conduction.

This does not bother a transformer coupled Class B stage because a common transformer is used for both output transistors. Each transistor draws current in one direction, but the net dc current in the transformer, due to push-pull, is approximately zero. Of course, dc current can flow through a transformer anyway without saturating, if it is appropriately designed.

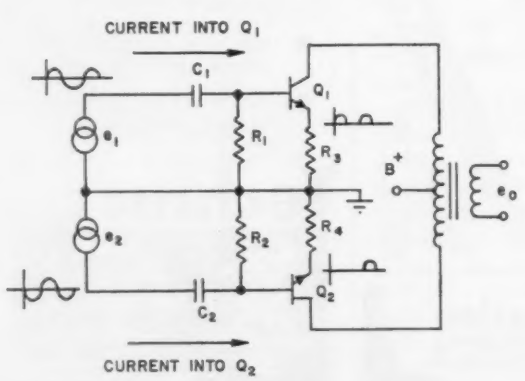


Fig 1 Simple Capacitor Coupled Class B Output Stage

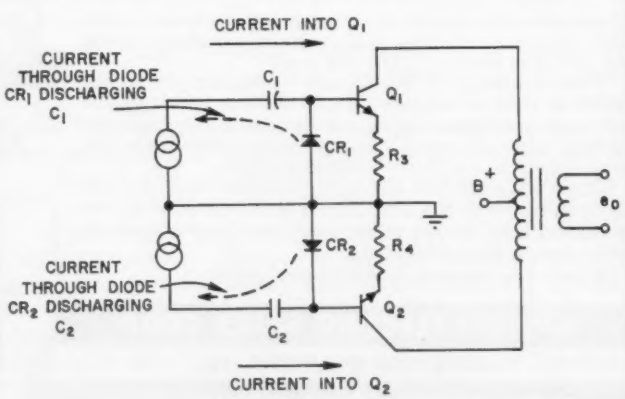


Fig 2 Capacitor Coupled Stage With Diodes

Summarizing the problems in coupling a Class B stage, we can say that the two most serious considerations are: (1) the coupling capacitor will charge if precautions are not taken and (2) very large capacitor values must be used to get much power into the output stage.

In Fig 1, transistor Q_1 begins to conduct and the direction of current flow is as shown by the solid line arrow. This charges C_1 since appreciable current flows in one direction only, R being much greater than the input impedance of the transistor. Q_1 is biased in Class C and the output is seriously distorted. This charging can be minimized by decreasing R_1 with attending loss of drive current to the transistor. A small R_1 will greatly reduce efficiency and increase phase shift through the coupling capacitor.

These problems can be avoided by using diodes in place of R_1 and R_3, as shown in Fig 2. Now when capacitor C_1 charges, as shown by the solid line arrow, it discharges through the diode as shown by the dotted line arrow. When the positive half cycle is on the base of Q_1, it conducts and charges C_1. CR_1 exhibits infinite resistance in this polarity. When the negative half cycle is on the base it biases Q_1 off and CR_1 conducts, discharging capacitor C_1. We can now keep C_1 effectively discharged without the power loss and phase shift associated with R_1 and R_2 in Fig 1.

One system cannot, of course, have all advantages and no disadvantages. C_1 and C_2 must be a large value to be useful at the lower frequencies and high power. In a Class A amplifier the input impedance at the base would be quite high (in the order of several thousand ohms for a small voltage amplifier) and a smaller coupling capacitor can be used. A power amplifier in Class B is an entirely different story and here the relationship between the base resistance and the capacitor impedance becomes very important.

Input impedance for large transistors can be in the order of an ohm or less. The more power we wish to get from the amplifier and the lower the frequency range, the larger C_1 must be. It is for these reasons that we begin to reach upper power limit for capacitor coupling.

Fig 3 shows how capacitance value increases with a power increase. Three curves were plotted to show the difference in capacitor values for three different transistors in the range from 200 milliamperes to 5 amperes. Note that the peak emitter current is used to determine the input base-to-emitter resistance. This will produce

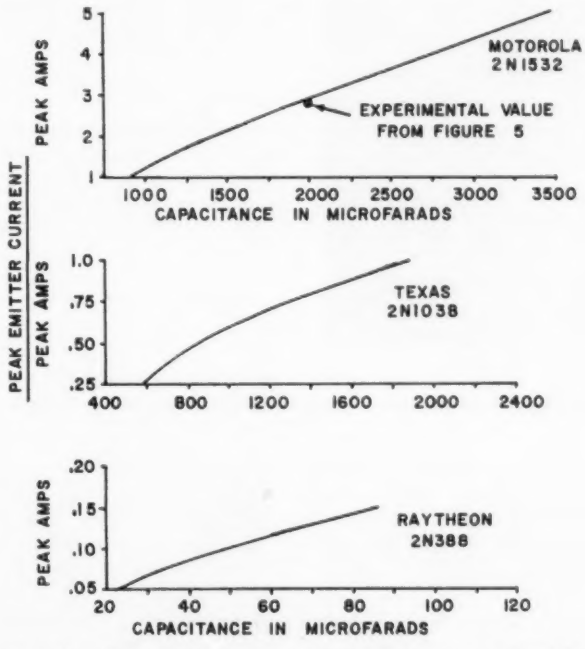
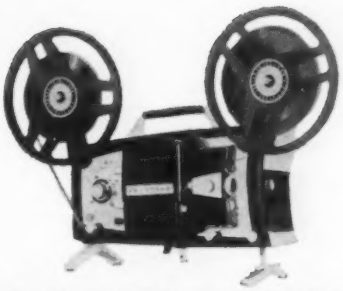


Fig 3 Required Coupling Capacitor For Class B Stages as a function of transistor and peak current. Note that these curves can be derived for any transistor by following this sample calculation:

1. **Using data curves on the Motorola 2N-1532, each peak current will produce a minimum input resistance; for example, 2.8 amps gives an $R_{input} = 16$ ohms.**
2. **For a phase shift of five degrees and a maximum attenuation of 0.1 db at 60 cycles;**

$$X_c = 1.4 \text{ ohms}$$
$$c = 1{,}900 \text{ microfarads}$$



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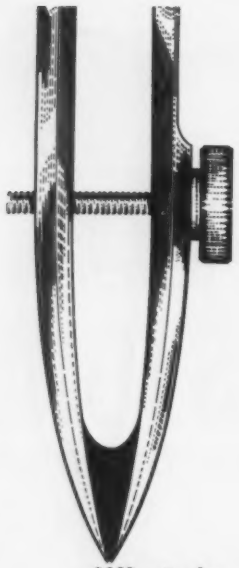

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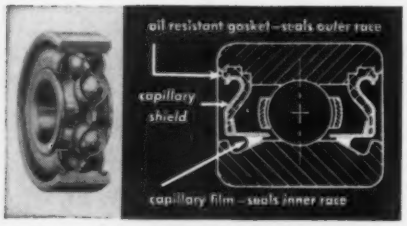

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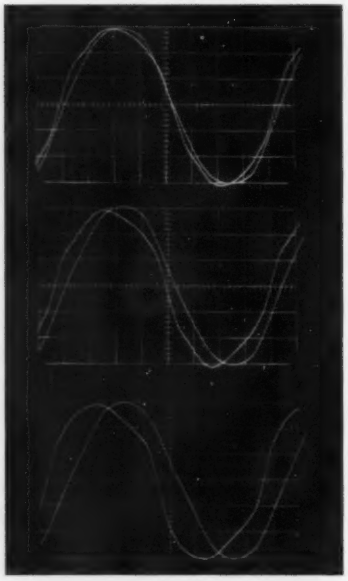

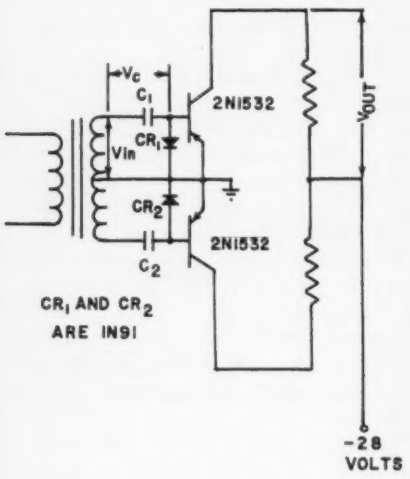

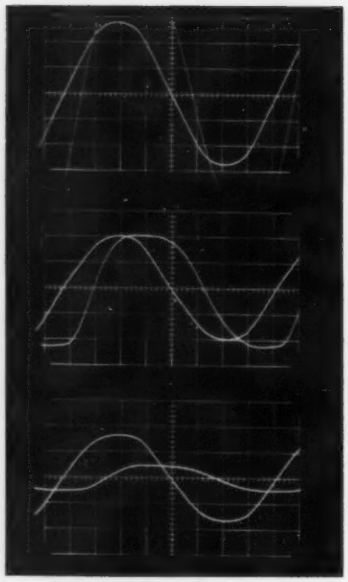

Fig 5 Attenuation and Phase Shift as a Function of Capacitor Value

UPPER V_c, voltage drop shown across C_1 and C_2 versus V_{in}, input voltage.

Top	**—**	**2,000 Mfd**
Bottom	**—**	**200 Mfd**
Center	**—**	**500 Mfd**

60 cycle input was used with output adjusted to 2.8 amperes peak current. V_c voltage not shown proportional to V_{in}. All V_c voltages are only relative to each other.

BOTTOM

Phase shift illustrated by use of various values of coupling capacitors with output current of 2.8 amperes peak. 60 cycle input used from A.C. line. Scope adjusted to 2 milliseconds/cm.

Upper	**—**	**2,000 Mfd**
Center	**—**	**500 Mfd**
Lower	**—**	**200 Mfd**

the minimum input impedance during the cycle which allows for a small safety factor in calculating the capacitance required. The transistors used were the Motorola 2N1532, Texas Instrument 2N1038 and Raytheon 2N388. For the curve, the following conditions were used: operation at 60 cycles, attenuation of 0.1db maximum across the capacitor and a phase shift of less than five degrees.

Fig 3 shows that for a peak output current of 1 ampere the Motorola 2N1532 would require a capacitor of under 1,000 Mfd. For the same current, but using the Texas Instrument 2N1038, a capacitor of approximately 1,700 Mfd. must be used for the same output conditions. This illustrates that a higher beta transistor will require a lower value capacitor. The high power limit can be increased by carefully choosing a transistor with a high beta since we cannot practically increase the capacitor value indefinitely.

Fig 4 is an experimental varification of the curves in Fig 3. Picture *A* demonstrates the phase shift through the output stage with different values of C_1 and C_2. Picture *B* demonstrates the attenuation across C_1 and C_2 as a function of their values.

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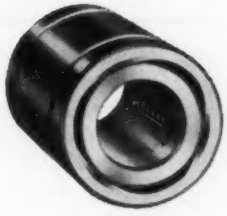

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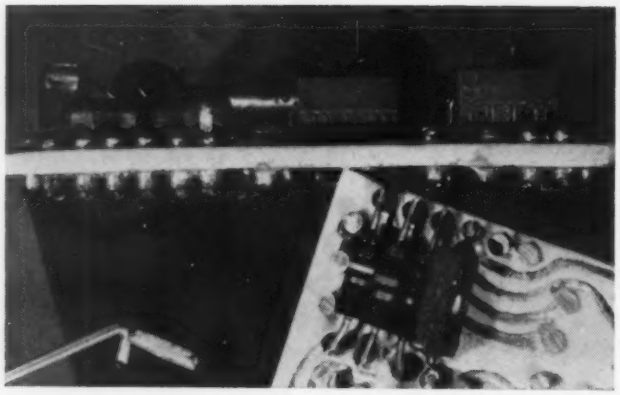

Fig 1 Two sided board as used in the above 500 kc flip-flop provided good packaging density.

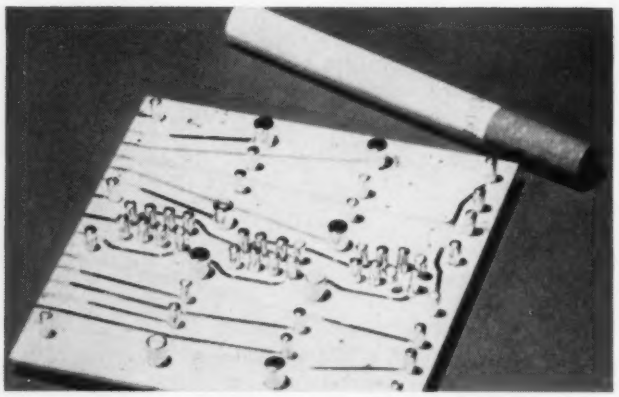

Fig 2 Beryllium oxide is used for the terminal board. Insert studs are made of Kovar.

THERMALLY CONDUCTIVE COMPONENT BOARD

Gerald H. Kriss and Louis J. Polaski, Missile & Space Vehicle Dept., General Electric, Phil., Pa.

With all circuit connections electrically insulated but thermally grounded, a ceramic component board assembly represents an excellent method of removing heat from components in applications where conventional means cannot be employed. Techniques in the development of this assembly, described here, are based on the authors' paper presented at the 5th Annual Conference of the PGPEP (IRE).

Equipment designed for space satellite applications cannot enjoy the luxury of air. Therefore, there can be no cooling by convection. Unfortunately, radiation provides very little thermal transfer at high operating temperatures. Maximum conducting paths between the heat generating components and a heat sink was the method developed to limit the maximum temperature of component parts. Criteria for the proposed design included requirements for a positive conduction path from both body and lead of every component to the vehicular heat sink, while maintaining electrical circuit integrity. In addition, the equipment had to meet powered flight environmental stresses and remain virtually unchanged under extended vacuum conditions.

Practical aspects of reliable manufacture precluded the use of other than tried and proven manufacturing techniques, especially since flight schedules had been set prior to the inception of the design effort. A commercial print wire board substitute developed by Mr. E. H. Cumpston, Jr. of General Electric's Advanced Manufacturing Services group at Schenectady, seemed to have many characteristics desirable in our application. Fig 1 depicts a 500 KC flip-flop packaged by Mr. Cumpston during an early feasibility study. First of all, component lead attachment was accomplished by an optimized welding procedure, secondly, intimate contact between the electrical circuit and the mounting medium was provided, thirdly, reasonable packaging density was achieved by the use of a two sided board.

Since Mr. Cumpston was interested in a substitute for commercial printed circuit boards, manufacture was simple and foolproof. Our first goal, thermal conductance, was not met by Mr. Cumpston's choice of ceramics since his decision had been primarily based upon commercial considerations. In addition, the temperature extremes of his design requirements had forced him to closely match the coefficient of expansion of the insert material and the ceramic. Beryllium oxide ceramic became our logical choice as a terminal board material since it has excellent thermal conductance and reasonably good physical characteristics. Beryllia ceramic bodies have seen only limited use as a means of achieving thermal transfer within electronic equipment during the last few years. They have, however, seen extensive use in the design of nuclear equipment.

Thermal conductance of beryllium oxide or beryllia, as it is also called, closely approximates that of some aluminum alloys and is at least ten times better than that of aluminum oxide, its closest competitor, over the operating temperature range of equipment.

"Berlox," a product of the National Beryllia Co., was chosen for our ap-

plication since its purity was extremely high, in the order of 99.5%. The body used (shown in Fig 2) is approximately 3 x 3 x .06 thick and is perforated with approximately 60 holes.

Kovar, an iron, nickel, cobalt alloy was used as an insert stud. Since its coefficient of expansion did not exactly match that of the body material, greater clearance than normal was provided between the insert and hole wall.

Circuit interconnection runs were provided by a printed circuit technique patterned upon that developed by the National Bureau of Standards for VT fuse application during World War II. The interconnection pattern was transferred to a stainless steel screen by a photographic process similar to that used in silk screen fabrication. Circuit runs were first formed by moly-manganese metalizing compound deposited on the body surface by means of the metal screen. Metalizing compound was hand-brushed into the insert holes at the same time. The body was copper plated after the metalizing compound had been fuzed to the ceramic by a firing process.

Next step in the process was to braze the inserts to the ceramic body. This was accomplished by standard vacuum tube techniques with the major production advantage of not requiring the normal vacuum tight braze. Body insert assembly was then copper and silver plated after appropriate cleaning cycles. Insert stud faces were sanded to provide bare Fernico surfaces.

SAMPLE DESIGN

Our next task was to choose a suitable circuit so that we could properly evaluate the concept. The first consideration, an RF circuit was discarded because it was felt that the advantages of packaging this type of circuit were so obvious that its proof would be of little value. It was decided, therefore, to package a portion of an electric commutator. This device has seen extensive service during the last few years, having been used on several R & D programs. The particular circuit, a multivibrator and emitter follower assembly had been previously packaged in both print wire board and epoxy cube configurations and had a known thermal dissipation of approximately 600 milliwatts. The epoxy cube module was then redesigned for maximum thermal conductance and for assembly to the ceramic circuit board (Fig 3).

Thermal analysis indicated that 0.060 leads were necessary to remove heat from the module; therefore, "Kulgrid" a nickel clad copper wire was used. This material provided the thermal conductance of copper and the welding advantages of nickel. Leads were brought out of the sides of the assembly so that the cube could be mounted directly to the ceramic body and the leads would then be in optimum location for welding to the circuit stud.

A two step potting procedure was used to provide maximum thermal conductance. Transistor cases, located at the bottom of the assembly were embedded in a silver-flake-loaded epoxy which formed most of the bottom face of the cube. The remainder of the assembly was potted with a mica-loaded compound having poorer thermal characteristics, but being a better electrical insulator. Since the time these modules have been fabricated, we have found an alumina-filled epoxy having equivalent electrical and better thermal properties than the mica-filled epoxy used.

Module and board assembly was simple; the mating surface of the circuit module was wet with an aluminum-filled epoxy compound, spacer beads were located in the soft epoxy and the module leads welded in place. Welding the leads positioned and held the module until the epoxy set (Fig 4).

Welding design is worthy of special note. Mr. Cumpston in his efforts to develop a simple welding technique found that by controlling the area ratio of the welded materials, good welds could be made with widely differing welder settings and pressures, even in the case of oxidized leads. During the weld cycle, the Kovar changes state and wipes the lead, thereby providing a clean surface during the weld cycle.

It should be noted that although the board is designed to mount twelve modules only six were used in this portion of the evaluation. The projected equipment assembly contains as many of these ceramic board module assemblies as necessary, each one clamped on two edges to an aluminum frame which forms the external equipment case. This in turn, is mounted to the vehicle heat sink. Interconnections between sub-assemblies are hard soldered to the pin extensions located at one end of the board and plates containing connectors from the ends of the assembly.

TESTING AND EVALUATION

Since a detailed theoretical analysis

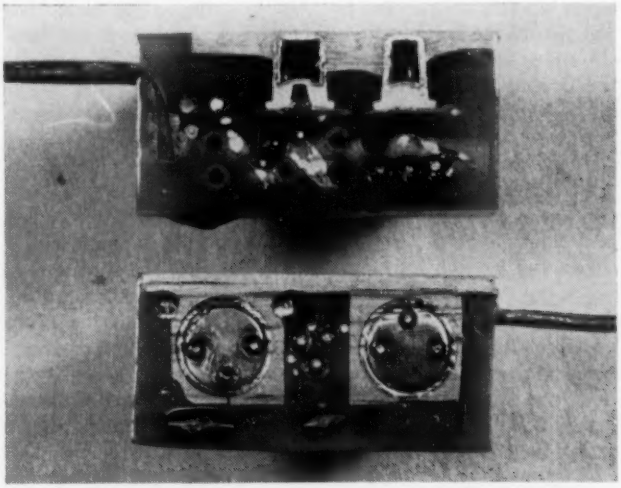

Fig 3 Cross section of epoxy cube module design with maximum thermal conductance for assembly to the ceramic board. This particular circuit, a multivibrator and emitter follower assembly, is a portion of an electric commutator.

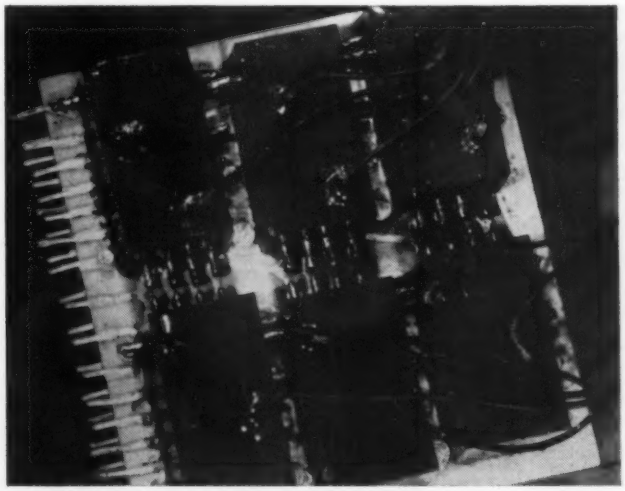

Fig 4 Individual circuits, encapsulated in epoxy parallelopipeds with large diameter nickel-clad copper leads, are potted to the ceramic board. Leads are resistance welded to Kovar studs which have been brazed into the board.

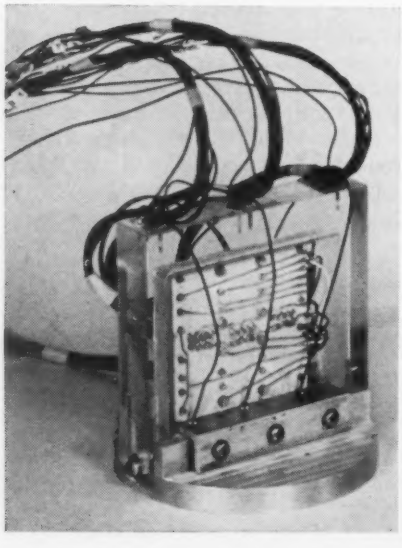

Fig 5 Test fixture consisted of an aluminum base and an adjustable inverted "U" shaped frame of polystyrene plastic. Component board was placed in the fixture perpendicular to the aluminum base. Top edge of the board was secured in a slot cut in the plastic frame; bottom edge was clamped to the aluminum base. The clamp, which simulated a possible method of edge clamping such as assembly to a "black box," consisted of "squeezing" the lower edge of the component between the riser of a step cut in the raised section of the aluminum base plate and the horizontal edge of an aluminum angle. This aluminum angle was attached to the base plate with screws which passed through the vertical side of the angle and the raised section of the base plate. Tension on these screws dictated the clamping pressure on the component board. During the tests, the fixture was thermally attached to a temperature controlled heat sink that was an integral part of the high vacuum test chamber.

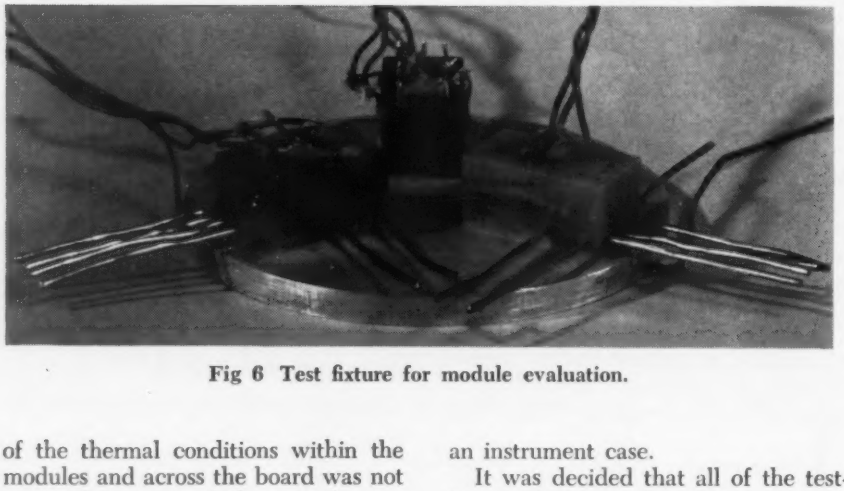

Fig 6 Test fixture for module evaluation.

of the thermal conditions within the modules and across the board was not practical because of the complex geometry of the assembly, a series of tests were conducted to evaluate the design. Test objectives were threefold. The first was to determine the approximate internal temperature conditions of the modules when they were energized in a high vacuum environment. This information was used to determine the effectiveness of the conductive heat paths designed into the modules.

Evaluation of the board's thermal transfer characteristics, the next test objective, consisted of examining the temperature gradient present in the component board, and determining the thermal resistance of the interface between the component board and the brazed Kovar pins. Third test objective was to determine the thermal resistance of a proposed method of edge clamping a component board to an instrument case.

It was decided that all of the testing would be conducted in a vacuum of the 1 x 10^{-4}mm H_g range. In such a vacuum there would be no heat loss by the component board assembly by convection. It was assumed that for the temperature range the assembly would be operating in, the heat loss by radiation would be negligible. Therefore, only the conductive paths designed into the assembly were available to transfer heat from the components to a heat sink.

A test fixture (Fig 5) simulating the proposed component board clamping arrangement was provided. Thermal conductance was supplied to only one edge of the board. This greatly simplified the measurement of heat flow and closely simulated the actual heat flow path that would be present in a "black box."

To evaluate the internal temperature of the modules, each module was instrumented internally during fabrication by the attachment of a thermocouple to a transistor case bead (the expected "hot spot") and a second thermocouple to one of the nickel clad copper leads (an expected "cool spot"). Testing of the modules was done in two steps. Modules similar to those attached to the component board were bonded to an aluminum plate which in turn was clamped to the temperature controlled heat sink (Fig 6). Leads of the module were thermally insulated from the heat sink. It was assumed that the heat transferred through the leads in this set up was negligible, and that the only mode of thermal transfer of the heat generated within the module was that of conduction through its base. Temperature of the transistor case, the module lead and the aluminum plate was monitored while the modules were energized in the vacuum. The second step of this test was to monitor the same temperatures in the modules that were attached to the component board. The component board test fixture permitted heat transfer from only one edge of the component board.

For both tests, the measured temperature difference between the "hot" and "cool" spots in each module was in the 30° to 5° F range. This uniformity in temperature can be attributed in general to proper placement of components with respect to their heat generating characteristics, and to the thermal conductivity of the potting compounds used. Test data indicated that the temperature difference between the transistor case and the heat sink to which the module was attached ranged from 8.5° to 10° F for those modules attached to the aluminum plate and from 6° F to 8° F for those attached to the component board. Temperature difference between the module lead and the heat sink, to which the module was attached, ranged from 5.5°F to 7.0°F for those attached to the aluminum plate and from 0°F to 4°F for those modules attached to the component board.

These results show that the leads of the module when thermally attached to a heat sink conduct an appreciable amount of heat away from the module. Tests have also shown that the component board is an excellent thermal conductor.

Second test objective was to evaluate the thermal resistance of the brazed joint between the Kovar pins and the component board. It was determined in the above test that the module leads dissipated an appreciable amount of the heat generated within the module. Therefore, it is

important that a good thermal joint exists between the Kovar pins to which the module leads were welded and the component board to which the pins were brazed. To investigate this joint, a component board that was identical to the one in the component board assembly was used. Several 1 watt carbon composition resistors were welded to specific Kovar pins to act as heat sources. The resistor cases were not thermally attached to the board. Therefore, when energized in a vacuum, the heat generated by the resistor was either radiated to its surroundings or conducted through the resistor leads, into the pins and into the component board. Total heat generated by the resistor was equal to the electrical power dissipated. Quantitative heat loss through radiation could be calculated by knowledge of the temperature of the resistor case. The remaining heat must, therefore, be conducted through the resistor leads. Test board was instrumented with thermocouples to measure the temperature at the center of each resistor case, the top of the resistor leads where they were welded to the pins and the surface of the component board, a short, known distance from the pin.

By analyzing the geometry of the test board and the power and temperature readings recorded during the test, it was estimated that approximately 15% of the heat generated by a resistor was radiated to the chamber walls. Heat lost by conduction through the thermocouples and the power leads was calculated to be approximately 1½% of the total heat generated.

Test results indicated that the joint between the pin and the board offered very little or no resistance to heat flow. This thermal resistance was determined by comparing the theoretical temperature drop from the top of the pin to the surface of the board (assuming no contact resistance between the pin and the board), and the same temperature drop measured during the test. In several instances the measured temperature drop was smaller than the theoretical temperature drop. At this time, this inconsistency can only be attributed to instrumentation error.

Both the component board assembly and the "component board-resistor" assembly were instrumented with thermocouples to measure the temperature gradient across the surface of the board. A simplified analysis of the thermal gradients indicates that the component board has a slightly lower thermal conductance than a homogenous board. This difference can be directly attributed to the pins inserted through the board.

To determine the thermal joint resistance of the component board edge clamping arrangement, the same test specimen (resistors mounted on a component board) was used. This joint was filled with a silicon grease to assume uniform heat transfer from board to the base. Thermocouples were employed to measure the temperature drop from the board to the clamp. Heat flow across this joint was equal to the difference between the total quantity of heat generated by the resistors and the heat radiated to the chamber walls. Therefore, knowing the temperature drop across the joint for a given heat flow and clamping pressure, a value for the contact coefficient of the clamp could be calculated.

Test results indicated that the clamping arrangement had an approximate contact coefficient of 0.45 watts/in°C. Approximate contact pressure between the clamp and the component board was 15 lb./in^2. If the same low contact resistance could be duplicated in actual "black-box" design, there would be no major problem in transferring heat from the component board to the instrument case.

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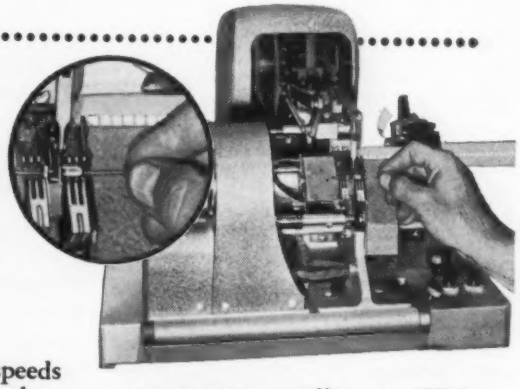

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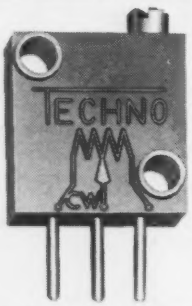
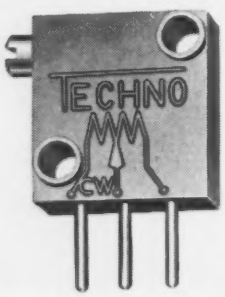
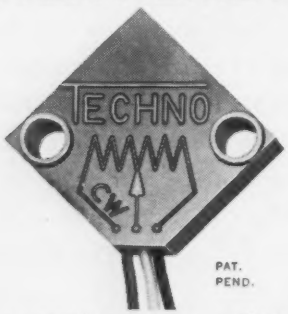


TRIMMING



POTENTIOMETER



Very small and very light (¾ gm), yet, MIL-SPEC tested and proven. Operating temperatures from −55°C to 175°C. Power rating: 1 watt at 50°C, derating to zero at 175°C. Resistance range: 10 ohms to 50K. Integrated plastic case design for high reliability. Available from stock. For additional data, write Dept. C.

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CIRCLE NO. 46 ON INQUIRY CARD

TESTING

DIODE TESTING

Magnetic Four Point Clip Eliminates Errors

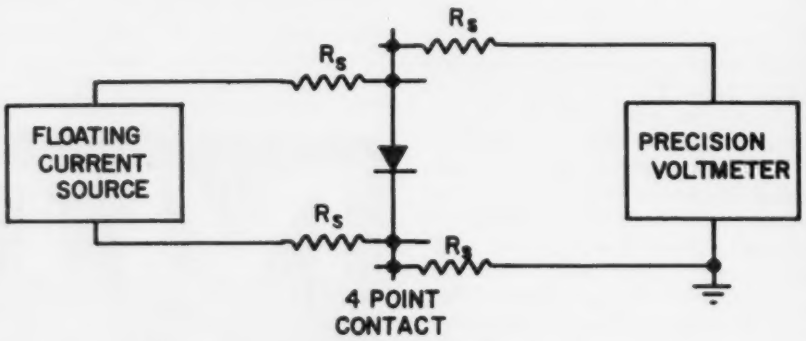

Fig 1 Four point test circuit eliminates spurious resistance errors. Forward current is supplied through one pair of diode connections; voltage drop is measured across the diode at the other pair of connections. In order to utilize this circuit effectively, it is most important that either the supply or the voltage measuring device be able to independently float one from the other so that the voltage drop across the leads and connections will not be shunted excessively by ground loops.

In testing diodes at high currents, the inclusion of the series resistances of leads, relays, wiring, and in particular the contact resistance of the diode clip, is a very common problem. At a typical measurement current of 100 milliamperes, these spurious resistances can create errors of 20 or 30 millivolts. Although this error may seem small compared to the one volt level at which diodes are often measured, Teradyne, Inc. reports that the distribution curve of diodes properly manufactured is only of the order of 20 millivolts wide. As a result even this small measurement error can seriously alter rejection rates. Where many units are tested, at a current level of one amp, the errors are of consequence.

Fig 2 Magnetic diode clip with four point connection used in Teradyne's diode tester.

A straightforward and well known solution to the problem, illustrated by the circuit design in Fig 1, is the use of four connections at the diode. Although this solution is widely recognized and its importance well under-

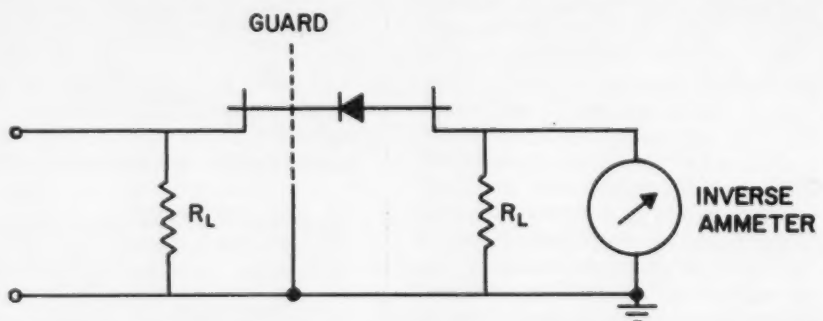

Fig 3 Grounded measuring circuit, with appropriate ground connection to clip, eliminates diode leakage currents.

How would you choose between these two coaxial connectors?

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The AMPHENOL connector line, on the other hand, offers you the most complete selection of UG-types available from a single manufacturer as well as *Push-On*®, *Quick-Crimp*®, and *Subminax*® connectors.

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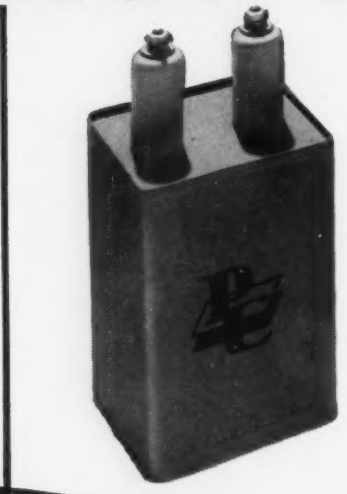

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stood, surprisingly few equipment employ it, according to Teradyne, because the design of a proper mechanical handling fixture that permits rapid and simple diode insertion, as well as four connections, has not been available.

To provide four connections to the diode, Teradyne has developed a magnetic diode clip (Fig 2) which gives ease of operation and simplicity of loading and unloading in their testing instrument. Magnetic contact force increases the reliability of simple pressure contacts and guides the diode rapidly into the clip. Slotted contact with opposing insulated connections provide a foolproof four probe connection, even when leads are quite badly bent and distorted.

In addition to the need for a four point connection, many diodes, tested for remarkably high inverse resistances, are often disturbed by the leakage currents across the insulation material used in diode test fixtures. Use of a guarded measuring circuit (Fig 3) and appropriate ground connection in the clip itself eliminates the leakage. By use of a guard, the leakage currents are effectively shunted to ground and do not appear as a measured diode leakage current. The Teradyne diode clip includes a guard connection for this circuit.

Another very important consideration in text fixtures, according to Teradyne, is the possibility in some designs of mechanical damage to the device being tested. Teradyne reported that their clip is not only incapable of distorting or nicking the diode leads, but has the advantage of not bending the leads. With some earlier approaches that have been used, Teradyne indicated, it was necessary to mechanically restraighten the diode leads after each testing operation, which involves as much effort and mechanical ingenuity as the testing operation itself.

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WORTH FILING

Tube Shielding

Curves and tables to aid in selection of the proper shield for a particular application are presented in a 16 page booklet. Cross-index of tube type and required shield is included. Catalog describes bezels for cathode ray tubes, gear drives, shaft locks, bearings, couplings, knobs, dials, and dial locks.

Source: James Millen Mfg. Co., Inc.
Malden, Mass.
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POTENTIOMETER TESTING

Fast Automatic Checkout of Performance Characteristics

Operating on principles similar to those employed by programmed automatic missile checkout equipment, Jonathan Electronic Corp.'s tester compares actual potentiometer voltage output with theoretical values at various incremental shaft positions. The Company, located in Fullerton, Calif., believes that their tape-programmed conformity tester offers the first completely automatic means of measuring deviation from predetermined voltage transfer functions.

Four functional elements – an angular index head, an eight channel punched tape reader, a control console and a dual channel oscillograph – make up the entire automatic test system. Index head consists of a holding fixture for the test sample and an electrical precision stepping mechanism for indexing the potentiometer shaft in angular increments of five degrees. Adapters are available for accommodating a wide range of shaft and body diameters.

Eight channel punched paper tape reader, which is attached to the console case, provides test function and sequence commands to the control section. Programming flexibility permits an infinite number of test points to be checked. Five decade stepping switches, controlling voltage dividing networks, generate the theoretical voltage value for each test point.

Panel meter displays reading in calibrated full scale values of 0.01, 0.05, 0.10, 0.50 and 1.0 per cent error. Permanent record of error is provided in strip chart form with the dual channel oscillograph. According to the manufacturer, an average potentiometer can be tested at 36 points in less than four minutes, with an average of two minutes required for set up.

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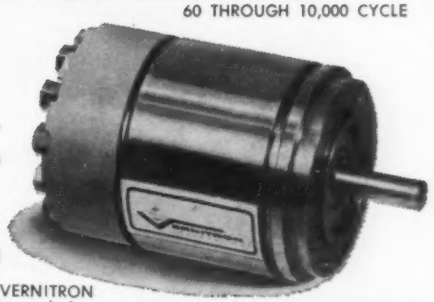

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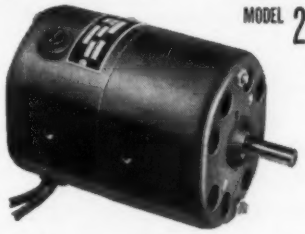

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	Shunt—1/12 @ 5,000 RPM	
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SHOWN ACTUAL SIZE

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CHARACTERISTICS

SYNCHROS

	VOLTAGE (400 cps)	T.R.	NULL (mv)	ERROR (min)
Transmitter				
CJO 0565 100	26	.454	34	10
Control Transformer				
Low Z-CJO 0555 100	11.8	1.765	34	10
High Z-CJO 0552 900	11.8	1.765	34	10
Differential				
CJO 0595 100	11.8	1.154	34	10
Resolver				
Low Z-CJO 0585 100	26	1.0	34	10
High Z-CJO 0589 100	26	1.0	34	10

SERVO MOTORS

	J126-06	J126-02
No-Load Speed	9800 rpm	9800 rpm
Stall Torque	0.10 in. oz	0.10 in. oz
Rotor Moment of Inertia	0.175 gm cm²	0.175 gm cm²
Voltage $\phi 1$ / $\phi 2$ (400 cps)	26 /36-CT	26 /26
Power Input /Phase	1.7 w	1.7 w

SYNCHRONOUS MOTOR

	CJO 0172 200
Pull-In Torque	0.06 in. oz
Pull-Out Torque	0.10 in. oz
Pull-Out Power	4 w

MOTOR GENERATORS

MOTOR.	CJ40812001	CJO0812650	CJO0813200
Voltage $\phi 1$ / $\phi 2$ (400 cps)	26 /36-CT	26 /36-CT	26 /26
Power / ϕ	1.5 w	1.5 w	1.5 w
No-Load Speed	8000 rpm	8000 rpm	8000 rpm
Stall Torque	0.10 in. oz	0.10 in. oz	0.10 in. oz
GENERATOR			
Voltage (400 cps)	26 v	26 v	26 v
Volts /1000 RPM	0.1 v	0.1 v	0.5 v
Null	1.3 mv	10 mv	6.7 mv

Size 5 gearheads range in reduction ratios from 20:1 to 1019:1 for servomotors and motor tachometers above. In addition to Size 5 clutches, brakes, and brake-clutches, Size 6 are available.

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KEARFOTT DIVISION
GENERAL PRECISION, INC.

Little Falls, New Jersey

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TESTING

Decade Voltmeter

Believed to be one of the most accurate ac voltmeters, Muirhead Instr.'s precision rms voltmeter has a wide voltage range of 1mv to 300 v and a useful frequence range of 5 cps to 100 kilocycles. Over the greater portion of this range, the measurement accuracy is 0.05% and the reading accuracy over the whole range is 0.025%. The instrument employs a unique bridge detector which is partially energized by a dc source. Balance is obtained when the dc plus the rms (heating) valve of the ac signal, adjusted by the four decade attenuators, reaches a predetermined value. Muirhead Instr., Inc., N.Y., N.Y.

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Two-Pen Recorder

In keeping with the demand for instruments which perform more than one function at a time, the Esterline Angus Instrument Co., Inc., Speedway, Ind. has developed a two-pen recorder that simultaneously graphs on a single chart any information which can be expressed in an electrical current or voltage. Its recording range is from microamperes to thousands of amperes and from millivolts to thousands of volts. In checking electrical circuits, one pen records amperage while the other records voltage, thus producing side by side synchronized graphs which reveal the effect of voltage variation on amperage. Other applications include checking the quality of arc welds and indicating the proper settings for anodizing.

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Digital Comparators

Formerly custom-built on special order, two fully transistorized digital comparators, equipped with mercury-wetted contact relays, are now available as production units. Providing a precise, fast, reliable way to determine if an input voltage or series of voltages is within preset limits, the units convert data from digital measuring instruments — such as ac and dc digital voltmeters, digital ratiometers, and digital ohmmeters — into go/no-go form. Go/no-go indication appears within 10 milliseconds in the form of contact closures, voltages and colored indication lamps. Both models operate with limits of either polarity and on any range. Non-Linear Systems, Inc., Del Mar, Calif.

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Inkless Event Recorder

Operating more than 50 days without a change in charts, an inkless recorder is immediately available in both a 10-channel model which sells for less than $500 and in a 20-channel model which sells for less than $600. Results from the company's torture testing of the styluses reveal they will last through more than 20 years of continuous operation and retain a response speed of 1/20 of a second. Special chart paper, with a non-wax finish, eliminates the danger of marred records caused by external heat, rough handling or discoloration from sun and other strong light. Esterline Angus Instrument Co., Inc., Indianapolis, Ind.

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Automatic Oscilloscope

Claimed to be the first solid state, 10 megacycle, fully automatic oscilloscope, the new instrument automatically displays a perfectly sized and positioned picture of waveforms regardless of input voltage magnitude, frequency or dc offset, according to the manufacturer. Complicated time-consuming adjustments and operator errors are eliminated through the use of automatic sweep speed, sensitivity, and positioning. Range of vertical sensitivity and horizontal sweep are presented digitally on proven nixie readouts. Calibrated dc offset is also presented digitally on an in-line display. Price is approximately $1500. California Instruments Corp., San Diego, Calif.

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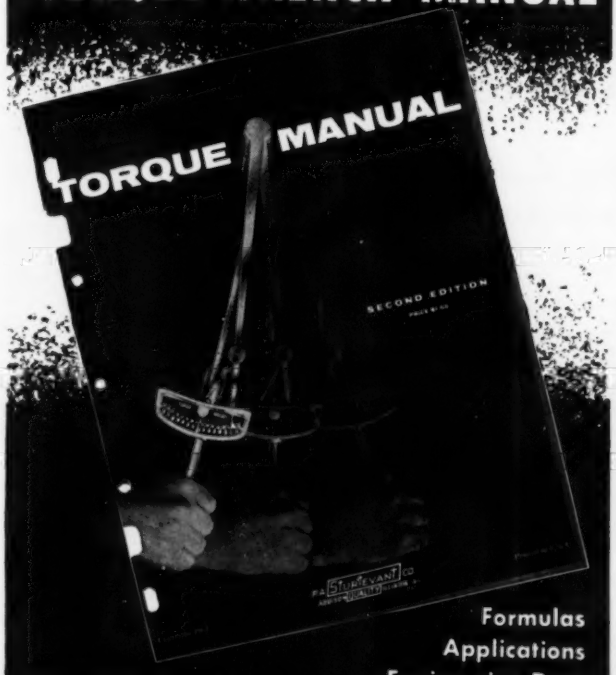

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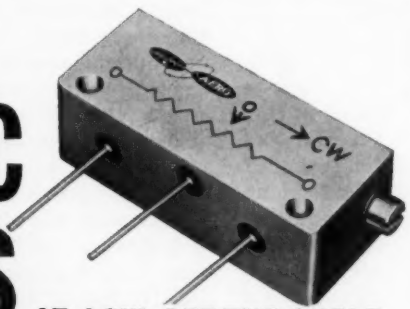

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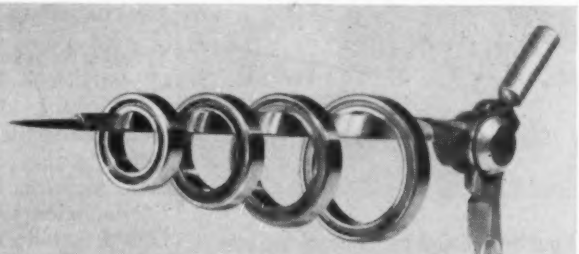

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This new series is manufactured to ABEC-5 precision standards or better, of 440C stainless steel, with plastic crown retainers which act as lubricant reservoirs.

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BORE +.0000 −.0002	OUTSIDE DIAMETER +.0000 −.0002	WIDTH +.000 −.001	BEARING NUMBER	RADIUS	LAND DIAMETERS INNER	LAND DIAMETERS OUTER	BALLS NO.	BALLS SIZE	C RATING
.3750	.6250	.1562	SR620T	.010	.457	.542	12	1/16	81
.5000	.7500	.1562	SR824T	.010	.587	.672	16	1/16	95
.6250	.8750	.1562	SR1028T	.010	.712	.797	18	1/16	98
.7500	1.0000	.1562	SR1232T	.010	.837	.922	22	1/16	108

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CIRCLE NO. 25 ON INQUIRY CARD

RESEARCH

ULTRASONIC TRANSDUCER

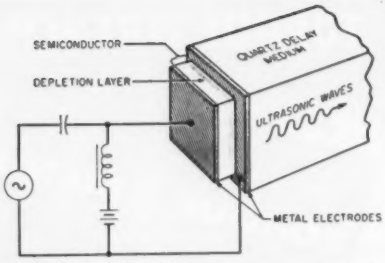
Semiconductor Depletion Layer Key To Efficient Generation Of Ultrasonic Waves At High Frequencies

Use of ultrasonic delay lines at high frequencies has been limited because ultrasonic waves could not be generated or detected efficiently at microwave frequencies, and furthermore, were considerably attenuated in the delay material. However, now in the early stage of development, at Bell Labs, is a piezo-electric transducer that generates ultrasonic waves with the greatest efficiency at under 1000 mc, and Bell expects to extend the range to above 10,000 mc.

In addition to its use in delay lines, the transducer may become a tool for studying the acoustical properties of materials at higher ultrasonic frequencies. Bell anticipates that large amplitude ultrasonic waves can be generated in materials at microwave frequencies and also extremely weak waves can be detected with greater efficiency than with existing transducers.

SEMI-CONDUCTOR LAYER

Bell's transducer consists of a plate of piezoelectric semiconductor (such as gallium arsenide) on which a thin metal film is deposited. The film constitutes a non-ohmic rectifying contact which causes a depletion layer to form. (A depletion layer is a thin region of high resistivity that forms at the interface of two dissimilar materials such as a p-n junction in a semiconductor or a rectifying metal-to-semiconductor



Schematic of Bell Labs new depletion layer transducer attached to a quartz crystal. With this highly efficient transducer, small electric signals generate ultrasonic waves and very weak ultrasonic waves can be detected.

contact. Difference in Fermi levels of the two adjacent materials usually gives rise to an internal electric field which sweeps or "depletes" the thin interface region free of mobile charge carriers, thereby increasing the region's resistance.) Thickness of the depletion layer, hence the resonant frequency, can be controlled with a negative bias voltage across the interface. This adds great flexibility to the transducer's use.

When an ac voltage is applied, most of the voltage drop occurs across the layer and the layer behaves in a manner similar to a very thin piezoelectric crystal which is bonded to a solid. Since the layer is thin, 10^{-3} to 10^{-5}cm, the electric field is very large and considerable piezoelectric stress can be produced.

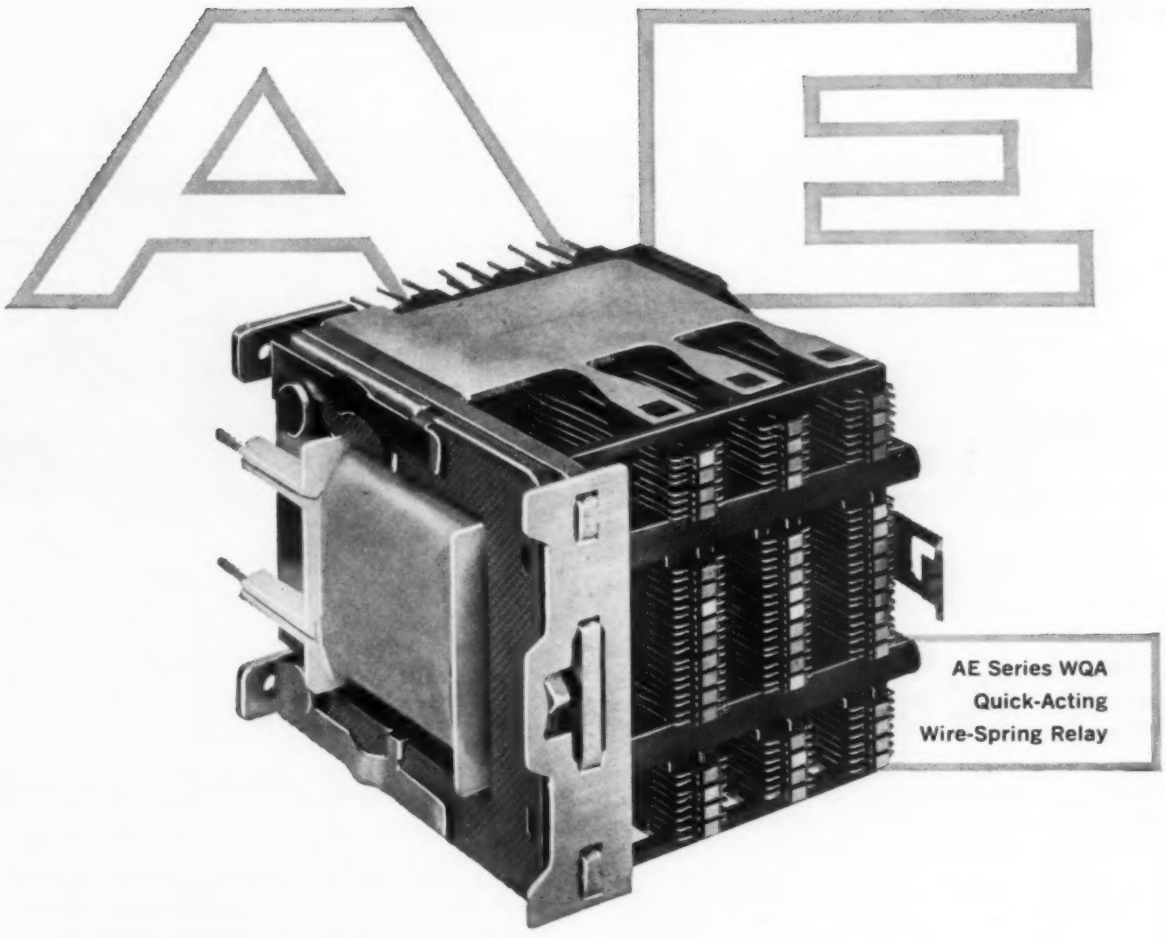
Present models measured at 600 mc have a bandwidth of 5%, an order of magnitude larger than typical ceramic transducers, operating at frequencies below 10 mc. Thus, a comparable increase should be expected in the amount of information which can be transmitted.

In experiments at Bell, the new depletion layer transducers operated well at frequencies as high as 830 mc. Bell expects that improvements in circuit and fabrication techniques will greatly extend the frequency range. • • •

Computer Built By Two Sings "Bicycle Built For Two"

Synthetic speech in response to the typing of phonetic symbols on a keyboard was heard by scientists at a meeting of the Acoustical Society of America. Doctors John L. Kelly, Jr. and Louis J. Gerstman of Bell Telephone Labs played several tape recordings of speech which had been synthesized by an electronic digital computer. Kelley and Gerstman had recently proposed a "speaking machine", but before actually building, they used a high-speed, general-purpose computer to simulate it. The program has two parts. One simulates the speaking machine; the other consists of rules for combining the individual speech sounds into connected speech and producing control signals corresponding to voice pitch, buzz and hiss intensity, plus the center frequencies and bandwidths of three speech formats. Speech comes out of the computer on digital magnetic tape and is then connected to a variable magnetic sound track suitable for playing on an ordinary tape recorder. Dr. Gerstman played a recording of a "Bicycle Built For Two" and also a few lines of "To Be Or Not To Be" — a non-mortal reading immortal words.

(What next for computers? — "They may perform stylish marriages; things are getting quite complex; But I'm afraid
They may invade
The area that's known as sex".)



TO THE ENGINEER

who wants to transfer 51 circuits simultaneously

If you need simultaneous transfer of a large number of circuits without fail, take a look at AE's new WQA relay. It will do the work of four or more heavy-duty, general-purpose relays each with maximum spring pile-ups, and sustain 50 million or more operations without readjustment.

In the WQA relay, all moving springs pass through holes in a unique actuating "card." Moved directly by the armature, the card in turn actuates all the moving springs. This method of operation pre-establishes exact timing and sequence of all spring operations, and at the same time assures perfectly synchronized "break-before-make" on all circuits.

Contact capacities on WQA relays can be custom-tailored to your needs, with either one, two or three levels of contact assemblies available, each with a capacity of 17 Form C combinations. Other Forms available.

Our circuit engineers will be pleased to work with you in adapting the WQA to your specific design. Or, if you wish, they'll take on the complete packaging job.

If you'd like more information on the WQA relay, address your request for Circular 1957 to: Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois.

AUTOMATIC ELECTRIC

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GENERAL TELEPHONE & ELECTRONICS

GENERAL SYSTEM

CIRCLE NO. 26 ON INQUIRY CARD

Do I Want to Go Public?

Here are some situations typical of those that face the small growing electronic or electromechanical manufacturer in deciding whether or not to "go public":

1. You have developed a product or service that has proved successful locally and has shown the potential of being equally successful on a regional or national basis.

2. Your new product's success has opened your eyes to the possibility that allied new products may be in demand.

3. Yours may be an old-line, conservative company with an excellent brand reputation, but now you desire to broaden your line to lower distribution and marketing costs.

4. You have developed a new applied science product which requires additional funds for manufacturing, distribution and continued research and development.

5. Your new sales program has proved highly profitable but you require additional funds for expansion.

6. Your company's industry position will be improved by the acquisition of additional concerns within the industry or outside the industry for diversification.

7. You wish to merge with several other small, independent firms to form a larger company with a new corporate image.

8. You want your company to be the first in your industry to establish a public market for its stock and use these funds as a basis for acquiring other privately held companies whose owner-managers may be desirous of cashing in their capital gains.

9. Your company needs funds for new equipment or new quarters.

10. Your company needs additional capital which could be used as a basis for establishing a higher credit line.

In Chicago the owner-manager of a small power supply manufacturing company sits alone in his office, wondering how to raise funds to meet his working capital requirements. Although his company has been growing at the rate of 25% per year, his accounts receivable are completely factored; most of his capital equipment is leased. Profits are going into taxes and interest payments on short-term loans from commercial banks. How can he build capital in a situation like this?

In Texas a semi-conductor manufacturer has made a breakthrough as a result of his company's research and development activities. He has made a large number of samples of his product and now needs funds to get into production. He is literally swamped with orders at very profitable prices. But since his original invested capital has been expended in the development of his new product, how is he to raise funds and yet keep control of his fledgling company?

In Philadelphia a small instrument manufacturer whose new proprietary item has been well-received in the last year now desires to add other proprietary items to his line. He is considering the purchase of one of his smaller competitors so that their combined products can be distributed more economically. But he has no funds available for such a purchase. How can he buy this company and still retain control of the combined enterprises?

All over the United States the owners of small but growing businesses are wrestling with the problem of how to raise funds. One way many of these companies can raise capital, of course, is by "going public" – by selling some of their stock to the public.

Often such a step raises fear and suspicion within those men who aggressively start new businesses and make them hum. Not only do they fear losing control of their companies, but their unfamiliarity with SEC regulations and the complexities of public financing makes the step seem

By Harvey C. Krentzman
President, Advanced Management Associates, Inc., 39 Old Colony Road, Chestnut Hill, Mass.

Mr. Krentzman, President of Advanced Management Associates Inc., Newton, Mass. & President of the Association of Management Consultants, Washington, D.C., consults with a variety of electronic and electromechanical small businesses. He's a director of several manufacturing companies and consultant to seven firms that have "gone public" or are currently in the planning stages. He holds degrees from Harvard Business School, Harvard Graduate School of Engineering and Northeastern University.

a frightening one. Price-earnings ratios, convertible debentures, stock warrants and relative yield performance are terms in the language of those who want to take the business away.

And if the small engineer-businessman does recognize the advantages of public financing, too often he thinks this is the way big businesses raise funds – not small businesses. The fact is that the public, thanks to the availability of money for investment in risk-growth opportunities, has displayed a remarkable interest in investing in small but growing businesses.

FEDERAL HELP

Three recent governmental enactments serve to stimulate greater public interest in small business investment.

• The Small Business Investment Act of 1958, intended to improve and stimulate the national economy, in general, and the small business sector, in particular, has done just that. It has encouraged the flow of private equity capital and provided long-term loan funds necessary for the sound financing of small business concerns who need money for growth, operations and modernization.

Federal income tax Amendments of 1958 now allow a stockholder who invests in a Small Business Investment Corporation certain tax advantages. Investors in SBICs can write off any loss on the sale of their stock against ordinary income – rather than take it as a capital loss. Any gains realized are, of course, taxable at the usual capital gains rates.

Thus there is a built-in snowball effect resulting from these two enactments. Specifically, when a SBIC takes a position in a small business concern (and usually places a representative on its board of directors), the chances of this company's going public, as it grows larger, are greatly increased – simply because going public will enable the SBIC members to profit by a capital gain on the sale of their stock.

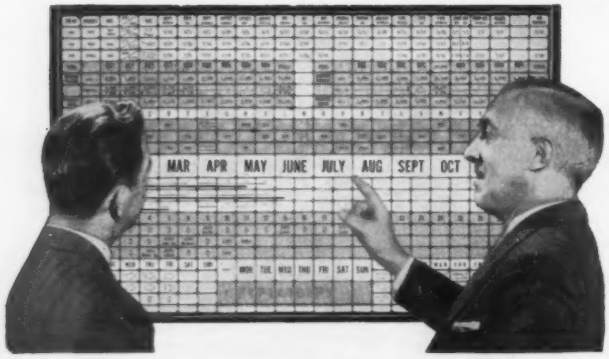
• Under the conditions set forth in Section 1244 of the Internal Revenue Code (as amended by the Technical Amendments Act of 1958), individual investors in a small business corporation are permitted to deduct as ordinary loss for any taxable year up to $25,000 ($50,000 for husband and wife), if the investment is made according to those conditions set forth in the law.

• The Technical Amendments Act of 1958 has stimulated investments in small businesses, also, since it allows a corporation having less than ten shareholders to be taxed as a partnership. Therefore, if the owners are in the 80% tax bracket and the company loses, say, $50,000, each of the ten owners sacrifices only $1,000. Thus, small groups of people in the higher income brackets become more likely to invest in risk-growth situations since their loss can be treated as an ordinary loss in the year it occurs.

These federal enactments definitely serve to fan the public's interest in small business investment. In effect, the government has seeded the growth of many companies that will want to go public in the future.

Through these efforts of Congress small businessmen find large sums available to them through private financing. Although such private financing (by definition) means ownership should be less than twenty-five persons, it does bring to an end many of the "one-man show" types of management many of these companies have had prior to accepting private financing. Once these companies become used to multiple ownership, the road to full public financing is made easier.

You Get Things Done Better By Seeing What's Happening



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CIRCLE NO. 27 ON INQUIRY CARD

new miniature
SYNCHRONOUS MOTOR

For the first time you can obtain the power-packed performance of a military precision synchronous a.c. motor at commercial motor prices. This may be just the motor you're looking for to miniaturize your design while enhancing the performance of your high quality product — recorder, business machine, timer, or other motorized device.

Quick specs: Type CMC motor has a starting and running torque of .7 oz. in. at 1800 rpm. synchronous speed. Wound for 115 v.a.c., 60 cycles, it uses 12 watts. It is 1¼" in diameter by 2¾" long, weighs 7½ ounces. Shaft is precision ground stainless steel supported by life-lubed ball bearings. Epoxy sealed design provides good resistance to normal environmental conditions. Please request Bulletin CMC-2. Globe Industries, Inc., 1784 Stanley Ave., Dayton 4, Ohio.

1¼" x 2¾"

GLOBE INDUSTRIES, INC.

CIRCLE NO. 28 ON INQUIRY CARD

WHY NOT GO PUBLIC?

If you are a growing small businessman, your ignorance of current trends can be a significant handicap when you seek to compete with competitors, better informed financially. Your concern with short-run problems of your business can lead you into future financial problems. Pushing constantly for increased sales, for greater plant efficiency, for new product developments and for greater profits *now* is an inevitable part of the smaller operation. Some of this preoccupation with immediate problems, however, arises out of the small company owner's despair over how he would ever obtain the financing to put over any ambitious long-range plans he might formulate.

Actually what such men need is to be reassured that public financing, if intelligently handled, will allow them to keep control of their company, and, at the same time give them funds which need not be paid back in the short run — as do bank loans. One of the best features of public financing is the fact that dividends are only paid at the time when the company can best pay them — when it is showing real profit.

Four paramount advantages accrue to the company that successfully receives public financing.

- Going public enables the principals to capitalize on a favorable price-earnings ratio to receive, quite possibly, more from selling only *part* of their company than they would get by selling all of it outright to an individual buyer.
- Public financing may increase the owner's personal income and protect the estate of the principals.
- Since the company can now offer shares in ownership to key employees, the company probably will be able to attract and keep exceptional personnel.
- The extra working capital thus obtained should enable the company to seize new opportunities for growth and profits.

The Price-Earnings Ratio

The real key to the advantages offered by public financing lies in the price-earnings ratio that can be established for your company. The exact ratio, of course, will be derived by the investment house underwriting your company's issue. It is arrived at after exhaustive study of the amount of profits your company has made, its anticipated future earnings, tempered by considerations relative to the risk, profitability and future of your entire industry.

What the price earnings ratio ultimately consists of is this. Suppose your company made net profits after taxes of $140,000 in 1960 and that you have 200,000 shares of stock outstanding. Your profit per share then would be

$$\frac{\$140{,}000}{200{,}000}$$

or $.70 per share. Now if the underwriters decide that

Norden minimizes magnetic encoder size

BuOrd SIZE 18 **GRAY-CODE MAGNETIC ENCODER**
SMALLEST AVAILABLE

NORDEN offers this new encoder for applications where the combination of exceptionally long wear and high speed operation in a smaller package are vital. Strengthen your system or product design with this new high standard of performance factors:

- **Smaller size.** 1.750" diameter achieved by advanced techniques of ferrite disc magnetization.
- **High-speed performance.** Offers accurate readout at speeds to 10,000 rpm.
- **Almost unlimited life . . .** since encoder is not subject to disc-to-brush contact and wear.
- **Very low-starting and running torque.**
- **Completely unambiguous output.**

TYPICAL SPECIFICATIONS

Total Count	2^8 Gray Code
Rev./Full Count	1
Moment of Inertia	21 gm-cm²
Output Voltage	3 volts PTP min.
Breakaway Torque	Less than .05 oz/in
Maximum Speed (continuous interrogate)	10,000 rpm
Slew Speed	10,000 rpm
Diameter	1.750"
Weight	Under 5 oz.
Temperature Range	—65° to +125° C.
Vibration and Shock	Conforms to MilE-5272A

Send for more information on this unit and

OTHER MAGNETIC ENCODERS NOW AVAILABLE: Gray multi-turn size 18 with count capacities of 8, 15 and 22 digits; V-scan binary size 18 with capacities of 7, 13 and 19 digits; binary coded decimal with 8-4-2-1 or 4-2-2-1 code; pure binary or cyclic units with counts of 100, 1000, 10,000. Special disc patterns and count capacities can be produced to your requirements.

Advanced Norden techniques are also facilitating the development of SIZE 11 Gray and V-scan encoders offering this same capacity.

NORDEN

division of UNITED AIRCRAFT CORPORATION

NORWALK, CONNECTICUT

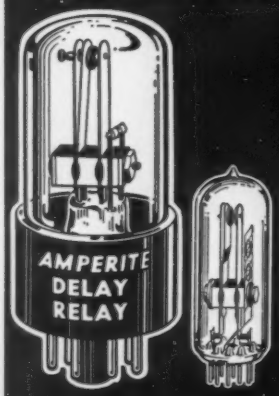
CIRCLE NO. 29 ON INQUIRY CARD

Large production gives you low prices!
– that's why...

Over 100 O.E.Ms have standardized on

AMPERITE

Thermostatic DELAY RELAYS



2 to 180 Seconds

Actuated by a heater, they operate on A.C., D.C., or Pulsating Current.

Hermetically sealed. Not affected by altitude, moisture, or climate changes.

SPST only—normally open or closed.

Compensated for ambient temperature changes from —55° to +80° C. Heaters consume approximately 2 W. and may be operated continuously. The units are **rugged, explosion-proof, long-lived,** and—**inexpensive!**

TYPES: Standard Radio Octal, and 9-Pin Miniature . . . **List Price, $4.00.**

Also — **Amperite Differential Relays:** Used for automatic overload, under-voltage or under-current protection.

PROBLEM? Send for Bulletin No. TR-81

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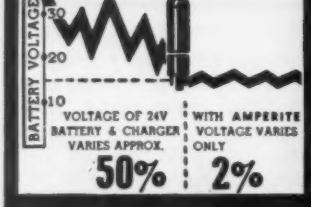
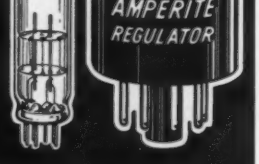
Amperite Regulators are designed to keep the current in a circuit **automatically regulated** at a definite value (for example, 0.5 amp.) . . . For currents of 60 ma. to 5 amps. Operate on A.C., D.C., or Pulsating Current.





Hermetically sealed, they are not affected by changes in altitude, ambient temperature (—50° to +70° C.), or humidity . . . Rugged, light, compact, most inexpensive . . . , ... **List Price, $3.00.**

Write for 4-page Technical Bulletin No. AB-51

AMPERITE

561 Broadway, New York 12, N. Y. . . . . CAnal 6-1446

In Canada: Atlas Radio Corp., Ltd., 50 Wingold Ave., Toronto 10

CIRCLE NO. 30 ON INQUIRY CARD

because of the excellent profit potential shown by your company (and by your industry) the public would be willing to pay $14 per share for your stock, a price-earnings ratio of 20 would have been set. That is, the price the public will pay is 20 times the earnings per share.

Now let us see how the price-earnings ratio can be used to enable owners of small but growing companies to raise capital without relinquishing control over their companies. Let us assume our Company has a net worth before stock issuance of $500,000. At this point, the business is worth $500,000, plus whatever premium a potential purchaser would set on its future profitability. How much of a premium would an individual buyer put on the Company? Perhaps he might at the outside pay twice the net worth of the company – or $1 million for complete ownership. But with a price-earnings ratio of 20, you can do much better by public stock sale – and keep control in the bargain!

Here's how it works: Of the 200,000 shares outstanding in your company, you, as a *selling* stockholder, offer 60,000 for public sale. At $14 per share, this brings you in $840,000. And you still have 140,000 shares of stock (worth $1,960,000) left – and still have retained 70% control over your company.

Let us suppose, next, that your company continues to do well in the market, and that your stock inflates to a price of $20 per share. Now you, as a selling stockholder, can arrange with the underwriter for a second issue of 30,000 shares. It must be understood that as a selling stockholder you may choose to raise funds either for yourself or for the corporation – or both. You can make this decision as time goes on, depending on your personal and/or corporation financial requirements. This second issue will bring you in an additional $600,000 – and you will still own 55% – or a definitely controlling interest in your company. Thus, by public financing you have raised $1,440,000 for the gradual sale of 45% of the ownership of your company. By selling it outright in the first place, you would have been lucky to get $1 million for 100% of your interest.

Is there any wonder that owners of small, growing businesses that can qualify for public financing have turned more and more to this method of raising capital?

Estate Protection

Sooner or later as the owner of a small company you must give serious thought to how you can best establish and protect your estate. Most owner-managers compensate themselves for their efforts through the medium of salary. Within this generalization are those who take barely enough to live on and plow the rest back into their companies, as well as those who feel that they can draw a considerably larger salary without hurting their company's financial position. But since, in most cases, the owner-manager's personal income tax bears such a close relationship to his company's, both men pay equally heavy taxes – so heavy, in fact, that it is almost impossible for either to build a significant estate in this manner. To prepare their estates adequately, both must look for a capital gains opportunity. In short, they must consider selling some of their stock to the general public.

But this step in itself is by no means adequate to guarantee the preservation of an estate. The owner-manager must recognize that one day he will retire. He must take early steps to insure, as much as is possible, that his company will not fall apart as soon as he leaves the

decision-making behind. The longer he postpones doing so, the greater is the risk he runs that the company that provides his basic security will flounder should he become unexpectedly incapacitated.

Attracting Key Executives

Certainly the basic requirement for continued operation of any business is a supply of experienced executives who not only are capable of keeping the company going after the death or retirement of the original entrepreneur, but who can make significant contributions toward the present growth of the company. But the small businessman constantly faces the problem of how to attract and keep capable people as part of his management group. How can the privately owned company compete with its bigger brother who offers not only many types of fringe benefits, but also, and most important of all, a chance for stock ownership?

Large corporations offer many types of plans designed to keep the producing manager a vital part of the company. Certainly, it is difficult for a very capable manager in a small company to refuse an offer from a larger company that offers stock, stock options, and/or stock bonus plans as part of the attraction, when his current position in the privately held, owner-managed company only offers "promises."

On the other hand, the small businessman who aggressively considers public ownership frequently can offer to potential executives greater opportunities for capital gains than can the larger companies. For, in smaller companies, each new breakthrough can bring a greater increase in corporate profits and consequently a faster rate of stock appreciation than most larger corporations can hope to achieve. Then, too, in the smaller corporation, there are the tremendous personal satisfactions that come to the manager when his ideas are quickly converted into corporate and personal profits. This is by no means an insignificant selling point in management recruiting.

In the management area, the privately held company which is operated as a one-man show really impairs its own future success. More small businessmen should realize this fact. A look at big business quickly shows us that it is wise to organize by breaking down operating responsibilities and giving authority to go with the responsibility. Once the personal goals of key executives are satisfied by a fair stock plan, or other executive incentive compensation plan, the owner-manager can then concentrate on the phases of the business in which he is most interested and qualified. This allows for faster corporate growth and fewer personal frustrations for the owner-manager. But when the "one-man show" type of owner-manager makes decision in areas where he is unqualified, the company inevitably heads for trouble. Essentially the one-man show can succeed only as long as the "one man" is secretly supported by a solid middle management group.

Without this middle management group, the typical small businessman conducting a "one-man" show employs

FULL TORQUE FOR 1,000,000 CYCLES

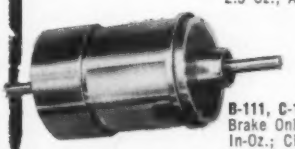
BOWMAR

Brakes, Clutches and Brake-Clutches

SIZE 8

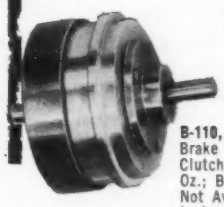
B-80, C-80, BC-80
Brake Only Torque: 8 In.-Oz.; Clutch Only Torque: 14 In-Oz.; Brake-Clutch Torques: 8 In.-Oz.; Length: 1.240 Inches; Weight: 2.5 Oz., Approx.

SIZE 11



B-111, C-111, BC-111
Brake Only Torque: 16 In-Oz.; Clutch Only Torque: 32 In.-Oz.; Brake-Clutch Torques; 16 In.-Oz.; Length: 1.485 Inches; Weight: 5 Oz. Approx.

'PANCAKE' SIZE 11



B-110, C-110
Brake Only Torque: 16 In.-Oz. Clutch Only Torque: 16 In.-Oz.; Brake-Clutch Torques: Not Available; Length: .5 Inches; Weight: 2 Oz., Approx.

Unique Bowmar design imparts **extra long** life to these precision components. You get full ratings (1000 hours or 1,000,000 cycles) throughout a temperature range of —55°C. to +125°C. Extremely fast operation is achieved in both types: 23 milliseconds for Size 11 units and 12 milliseconds for Size 8 units. Bowmar can produce these units as basic components; or they can be supplied assembled with Bowmar servo motors, gearheads and other components depending upon your performance or package requirements.

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PRECISION MECHANICAL COMPONENTS, PRECISION COUNTERS AND INDICATORS, PRECISION TIMING AND PROGRAMMING DEVICES, PRECISION ELECTRO-MECHANICAL DEVICES, PRECISION SERVO PACKAGES

CIRCLE NO. 31 ON INQUIRY CARD

a great deal of time, skill, and ingenuity in controlling the flow of funds for equipment, production materials, overhead, and so on. As a practical matter he frequently finds himself spending a disproportionate amount of time on operating details. If only, he laments, he could spend this time and energy in working out a new merchandising plan, in on-the-road selling, or in developing a new product in the laboratory. If only he could do this and leave the problems of finance to others.

But this can never be in the small company, for here only the owner and major stockholder really worries about what is happening to the assets of his business. Frequently we hear such laments as —"Doesn't Bill realize he is wasting company money? I'll bet if it were his money, he'd watch it more closely." A simple cure for such complaints is to give key managers a chance at stock ownership, a chance that is made more feasible when the company is publicly financed.

But even more important, perhaps, is the owner-manager's worrying over his ability to finance the continued growth of his enterprise. The first day he conceived of going into business, he worried about money; today, he worries just as much.

Despite all the time he spends thinking of financing, the typical small businessman really does not understand the ways of the financial community. One of the built-in advantages of going public (as you will see in detail later) is that the principal will be forced to pay attention to his financial advisors. And this, whether he chafes under the restraint or not, usually brings about real maturity in the handling of the company's financial affairs.

QUALIFYING FOR PUBLIC FINANCING

When an owner-manager decides to raise capital by going public, he ought to get expert advice before he acts upon his decision. If he doesn't, and relies completely on his own ability to "shop around" to find the "best deal" offered by an investment house, he may be heading for disappointment. The investment broker looks at his company's situation largely from a financial point of view. Whether going public is the best move for any individual business is a decision that requires a broad, yet personal outlook. This outlook can best be obtained from the composite view of those who know the business and the businessman's personal aims — best.

The owner-manager, therefore, will do well to listen first to his company's lawyer, auditors, and its banker. Their personal advice should be of considerable value. Then, ideally, he should consult one of a growing number of small business investment consultants. (For the purposes of improving standards of management consulting services to small business and establishing a Code of Ethics, the Association of Management Consultants, Inc., has been formed. The group's address is 1223 Connecticut Avenue, N.W., Washington 6, D. C.) For it is absolutely crucial for him to select just the right investment house for his company's stock issue. Picking the wrong house may lead to being refused underwriting — for reasons that might have little or nothing to do with the merits of his proposal. And a very few refusals will give his company's stock proposition a shop-worn look.

There are literally thousands of investment houses, many specializing by particular industry or by the size of the issuing concern. It is up to the owner-manager — with competent advice — to select just the right one.

But just picking out an investment house does not necessarily mean that your company is acceptable, and that the house will immediately underwrite your issue. All reputable investment brokers require that the companies they underwrite meet the following qualifications:

1. *The products or services your company markets — or will market — must evidence strong growth possibilities.*
2. *Your company must show excellent promise for continued increase in sales and earnings.*
3. *The company must display a strong management team.*

Once, however, your company has qualified for underwriting by the investment brokerage house, it is difficult to see how you can fail to benefit by going public. If the investment broker is satisfied that your company meets its standards, it guarantees, in effect, a certain return on your stock, less, of course, brokerage fees and costs of

STATISTICAL COMPARISONS OF SEVERAL GROWING ELECTRO

		Electronic Rsch. & Dev.	Electronic Material (Semicond.)
Sales	1956		
	57		
	58		$125 000
	59	$1 000 000	800 000
	60	1 900 000	1 500 000
Earnings, after taxes	56		
	57		
	58		16 000
	59	29 000	75 000
	60	64 000	145 000
No. Shares Authorized		1 000 000	850 000
No. Shares to be Outstanding		400 000	525 000
No. Shares Offered		50 000	135 000
No. Stockholders Shares Offered		30 000	60 000
% Shares Offered/Shares to be Outstanding		12.5%	25%
Offering Price/Share		$14.00	$15.00
Value Stock Sold		700 000	2 025 000
Earnings/Share Outstanding	1956		
	57		
	58		.04
	59	.21	.20
	60	.26	.33
Offering Price Earnings Ratio		54X	45X
Net Worth before Issue		1 000 000	450 000
Market Value of Outstanding Stock (at issue)		5 600 000	8 000 000
Stock distribution cost (% issue price)		9%	9%
Expense of Offering		40 000	35 000
Underwriter Options/Warrants		2 500	

flotation. Stock underwriting costs range from about 11.5% of proceeds for flotations between $1 and $2 million to approximately 22% for flotations smaller than $500,000. As for type of stock to issue, the investment house handling the underwriting will help you decide whether the public will prefer common stock (usually the most successful for small businesses), preferred stock, or debentures.

HOW AND WHEN?

But this, of course, jumps over the big decision. How should you go about making up your mind about how and when to go public: One of the first steps in making any decision is to make sure you ask yourself the right questions. Here is a list of those, which in my experience, have proved the most perplexing to small businessmen facing this decision:

1. *What volume of sales is it necessary for my company to have? What rate of sales growth is important?*
2. *What must my minimum net worth be?*
3. *How much profit should the corporation be making and for how long?*
4. *How does my company's price-earnings ratio compare with those of other companies both in and outside of my industry?*
5. *What are the chances of a personal versus a corporate stock flotation on a first public issue?*
6. *How much of my personal control must be relinquished on a first offering of stock?*
7. *What will it cost me to distribute and float my stock?*

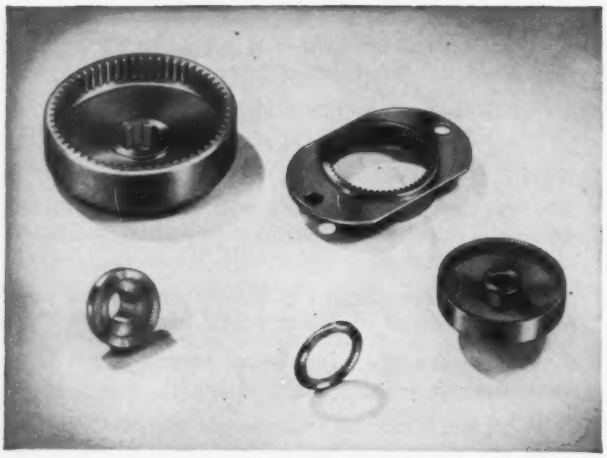
The answers to all these questions can be found if

TABLE I

D ELECTROMECHANICAL MANUFACTURERS STOCK OFFERINGS FOR WHICH THERE WAS NO PREVIOUS MARKET*

Electromechanical Instruments	Missile Comp. Mfg.	Electromechanical Military & Industrial Components	Electromechanical Missile & Aircraft Controls	Electronic Semiconductor Components	Microwave Components
$3 000 000	$3 500 000	$2 800 000			$1 100 000
4 100 000	5 200 000	3 300 000	$11 000 000	$220 000	1 400 000
5 600 000	5 500 000	3 750 000	10 000 000	670 000	2 200 000
2 200 000	7 000 000	4 500 000	14 500 000	1 900 000	2 800 000
2 400 000	8 000 000	6 500 000			
66 000	180 000	160 000			25 000
47 000	300 000	177 000	390 000	6 800	25 000
33 000	340 000	200 000	(50 000)	148 000	38 000
37 000	350 000	230 000	400 000	140 000	55 000
54 000	490 000	320 000			
1 000 000	1 500 000	321 000	1 000 000	500 000	850 000
255 000	1 000 000	386 000	550 000	285 000	340 000
100 000	250 000	130 000	175 000	110 000	100 000
	250 000	65 000			
40%	25%	34%	32%	38%	30%
$5.00	$13.50	$17.00	$9.00	$3.00	$6.00
500 000	3 429 000	2 210 000	1 575 000	330 000	600 000
.43	.18	.51			.11
.30	.29	.55	.71	.04	.11
.21	.34	.62	(.09)	.27 (issue)	.16
.24	.34	.72	.73	.50	.23
.35	.47	.99			
14X	29X	17X	12X	11X	26X
750 000	2 000 000	1 500 000	2 700 000	130 000	370 000
1 275 000	13 500 000	6 500 000	4 950 000	855 000	2 040 000
10%	7%	8.8%	9.5%	15%	10%
33 000	67 000	60 000	40 000	18 000	30 000
5 000				10 000	16 500

** Figures are taken from actual companies*



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you will examine Table I which is based on a study of over seventy-five public common stock issues. This study covered over twenty different industry groups geographically representative of the entire United States.

Let us assume, for example, that you are the Missile Component Mfg. on Table I and wanted to use this chart to help you answer each of the above qualifying questions:

On Table I you can see that this typical company's sales went from $3.5 million in 1956 to a steady $7 million after 1958. This does not show a staggering amount of growth, but the 1960 profit margin appears to be on the increase.

The stock was issued to the public at $13.50 per share for the 250,000 shares offered. One million 500 thousand shares were authorized; 1,000,000 were issued. Of these, 250,000 were sold to the public. The remaining 750,000 were owned by the controlling stockholders. The entire 250,000 shares were sold to the general public by a selling stockholder.

The total number of shares on the market was 250,000, which represent 25% of the total number of shares outstanding. Control thus was still within the hands of the principals.

The net worth of this representative electronics company before issue was $2,000,000. Its price-earnings ratio was 29. (How this compares with other electronic and electro-mechanical industry ratios can be seen at a glance across the columns.) Stock distribution costs were 7% of issue price, and expenses of flotation were $67,000. The underwriter took no options or warrants on the issue.

So in this actual case, the company raised $3,375,000 — a figure that exceeded its net worth prior to stock issuance — and the principals maintained control of their company by virtue of retaining 75% of the outstanding stock, in addition to receiving over $3,000,000 as selling stockholders.

RECENT HISTORY

What happens after the stock is issued? Are there further advantages that may accrue to the principals who decide to go public?

In the case of the electronic Semiconductor Components company (Exhibit A) the personal financial history of the two major partners presents a remarkable success story.

This electronics company was formed late in 1956. Its financial growth can be seen in the exhibit. The company decided to "go public" late in 1958, with the offering being accomplished early the next year. The initial issuance of 110,000 shares of common stock was readily purchased at $3. The stock had a rapid rise during 1959, reaching a high of $25 on the over-the-counter market before the Board of Directors voted a 2½-for-1 stock split.

About one year after its entrance on the market, the stock became listed on the American Stock Exchange and was selling in late 1960 at a range of $11 to $16. The initial share of stock purchased at $3 is currently valued at from 9 to 14 times the original purchase price.

About nine months after the initial stock flotation, the company required additional financing to help with its program of expansion. The company then sold $500,000 of 6½% convertible subordinated debentures.

The company has exhibited increased sales with increased earnings. As a result, its securities have met a waiting market. The company is currently preparing for its next stage of growth through possible acquisitions of smaller companies that exhibit excellent growth potential.

How has the original principals' personal equity developed through this period of rapid growth and public financing: At the time of the initial stock issuance, the partners owned 150,000 shares representing a value of $450,000 at the $3 opening price for their common stock. The net worth of the company at that time was approximately $350,000. At current market price for their stock, the equity of the original major partners has increased to a stock value of over $5 million.

This is indeed an example of amazing growth and is obviously far above the average. But the opportunity to succeed does exist. And this case clearly shows the tremendous personal capital gains earnings potential that exists when an individual or a group is able to manage and finance intelligently a growing small business.

NEW RESPONSIBILITIES

Before an owner-manager of a small concern rushes into public financing in order to obtain its decided advantages, he needs to be cautioned that there are new responsibilities such action will entail. Paramount among these is the fact that he must be willing to surrender some of the direct personal control of his company's every act that he formerly exercised. Also he should be aware of the fact that he must be less secretive about the facts and figures of his company's operations than he has been up to this point.

Most owner-managers are inclined to share even with their co-workers very few – if any – operating figures. Such matters as dollar sales, shipments, and earnings all become as sacred as Holy Writ. The one exception to this generality occurs when the owner-manager receives poor operating figures from his accountant. Then he is more than ready to divulge the facts of the business as a basis for exerting more pressure on his management group.

The owner-manager of the small, growing business must develop a mature long-range attitude towards his business. Understandably he identifies himself personally with his business; if the business is profitable he is happy and vice versa. Recognizing that perhaps all his personal assets are also tied to the business, there can be little understanding by his employees of this extremely close personal identification.

But a change in attitude must occur on the part of the business principal when he enters the public market with his securities.

Realistically a change in attitude or a maturing in attitude should develop, since with the entrance of his corporation's securities into the market, a means is developed whereby the future financial problems of the business can be more readily solved in addition to his personal equity and estate problems.

As the head of a public corporation, the principal stockholder must set operating policies that recognize his new responsibilities to his stockholders. These responsibilities are governed nationally through the Securities and Exchange Commission which administers both the Securities Act of 1933 (which relates to sales of securities), and the Securities Exchange Act of 1934 (which regulates securities trading on exchanges).

Upon going public, the corporation must prepare a registration statement and make subsequent disclosures of detailed facts about the company's business, operations, and finances which may never before have been made known outside the company. Now nothing is sacred. Particularly sensitive areas – like the pay of officers and directors, the interests of insiders in certain transactions, the security holdings of officers, directors and controlling stockholders, as well as dollar figures for sales, costs of sales, and gross profit – do not escape inspection.

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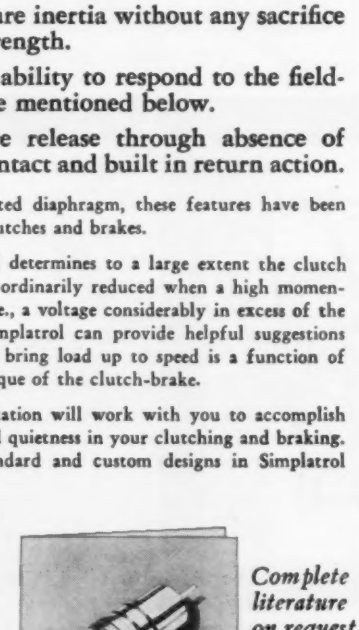

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MANAGEMENT

The corporation must also report monthly on all transactions in the company's equity securities, and this information is made available to the public. The principal shareholders must exercise caution in trading in the company's equity securities. If an officer, for example, buys shares of the company and then sells them within six months at a profit, that profit inures to, and is recoverable by, the company. Also on a sale and purchase within six months, the gain, if any, may have to be turned over to the company. It is well for the owner-manager at least to be familiar with the rules of the game before he decides to play.

Prior to going public the pressure on management to operate profitably was self-directed; however, as a public corporation, additional pressures are introduced, from the investment broker, new stockholders, suppliers, and competitors. Although the owner-manager still has operating stock control of his enterprise, his obligation to succeed is broadened. He must now begin to consider the effects of certain business risks on the larger stockholder group.

Even the annual meeting (which prior to going public was a routine affair) now becomes an interesting demonstration of democratic capitalism in action. Now, the new stockholders have an opportunity to speak, and the manager may not always like what they have to say.

THE BOARD OF DIRECTORS

The manager no longer stands alone as he faces the many hundreds (perhaps thousands) of new stockholders, and the S.E.C. The growing, small business man can now share his burdens with his board of directors.

If he is wise, the manager will have an opportunity to select a board of directors which will help him guide his business to even greater successes. As a small business begins to grow to medium size, the owner-manager must take inspiration from his larger corporate brothers whose continued growth and success has been guided by many varied types of board of directors groups.

The board of directors group that represents the stockholders is a valuable management tool rarely used effectively by small businesses. Perhaps this is due to the small businessman's lack of understanding of its purpose, perhaps to his unwillingness to accept suggestions, or perhaps due to the fact that it is difficult to get capable businessmen to serve on the boards of privately held companies. Such service, it often is felt, offers little in the way of personal prestige or profit, since offering direction to a single major stockholder who is also the president of the company often becomes mere sham.

But once the business has gone public, these objections to service on a board of directors dissolve. Now the board of directors really have a function of authority. As a result the aggressive small businessman has an opportunity to attract excellent business talent to help him in the many areas where his lack of specific business know-how needs to be bolstered. END

Military Transformers

How specifications affect transformer design and the effect of design parameters on construction are included in a 28 page booklet, along with a table showing the characteristics of common rectifier circuits. Metal-cased, hermetically sealed transformers and inductors are described.

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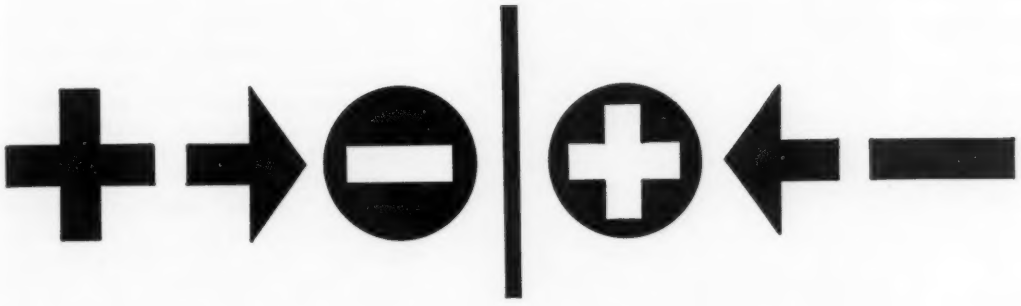
COMPONENTS DIGEST 21



Semiconductor Devices in Electromechanical Engineering

PART IV — TRANSISTOR AND DIODE TESTING

Increasing application of semiconductor devices in electromechanical equipment imposes problems on the electromechanical engineer in testing these devices to assure satisfactory equipment performance. This section of the Digest series on semiconductors is limited to testing transistors and diodes for low frequency applications. Testing high-frequency performance of these devices, such as for high-speed switching where transient characteristics are of prime importance, will be covered in a future part of this series, following further development of background theory necessary to an understanding of semiconductor high-frequency characteristics.

Testing of diodes and transistors, in effect, starts with the breadboards devised by the circuit design engineer. Here a working model, perhaps not yet in a final package, is available. The circuit currents and voltages may be measured and observed on an oscilloscope with particular regard to transient phenomena, since even microsecond pulses are very significant in establishing transistor voltage ratings. Satisfactory performance in the actual "use" circuit must of course be included among methods of test. Let us consider this factor in more detail. The breadboard circuit must be tested under extreme as well as nominal conditions. These extreme conditions include extremes in the parameters of the semiconductor itself due to manufacturing tolerances, as well as extremes due to temperature, ageing, and shifts in the operating points, changes in the external circuit elements, and of course extreme conditions of the power supplies. These breadboard tests are most satisfactorily carried out with a good oscilloscope having a bandwidth of at least several megacycles. This bandwidth permits observation of narrow pulses and steep wave fronts which may introduce damaging transients in the semiconductor circuit. Suitable voltmeters, together with the oscilloscope, permit study of most circuits from the point of view of establishing parameters for the semiconductor devices. For more complete studies however, particularly in high-frequency applications, much additional equipment is required.

On the basis of the above investigation, which the electromechanical engineer carries out in close liaison with the circuit designer, a good quantitative indication of circuit voltages, currents, and waveforms is obtained. This indication is obtained where feasible under extreme operating conditions. In particular, extremes of temperature and power supply voltages are checked. The type of data obtained relates to the parameters influencing performance as well as to the parameters affecting safe operation of the semiconductor. The latter parameters include peak voltage, peak current, and peak power ratings. Because semiconductor devices increase sharply in price where breakdown voltages exceed standard values, or where performance parameters must be held to within tight tolerances, effects on performance and on safe operation should be carefully checked. The semiconductor manufacturer will often assist in this phase by supplying selected units of extreme parameter values for checking out on the breadboard to set tolerances. At this same time, theoretical analyses by the circuits designer, leading to figures for circuit and semiconductor parameters and tolerances, should be corroborated with the above experimental results. Because the semiconductors are often the most costly components of the product, it is particularly sensible to review circuit details, tolerances, and parameters with the semiconductor manufacturer.

At the conclusion of this phase of the program, requirements on the semiconductor under extreme operating connections are known. There are the performance parameters, thermal characteristics, and peak voltages and currents. Furthermore, the engineer now understands which parameters

COMPONENTS DIGEST

are most important. Comparison with manufacturers data reveals which parameters are most marginal, and therefore most apt to cause trouble.

We are now at the point where we consider methods of checking the semiconductor to assure adherence to the specifications that have been established for satisfactory performance. We will by-pass questions relating to qualification and production testing, sampling procedures and such. These have been well covered elsewhere. In the small plant with production quantities not in excess of several thousand, it should be relatively easy to set up suitable procedures to fit the application.

ELEMENTARY TESTING PRINCIPLES

In this section we review some elementary test procedures based on principles that allow unsophisticated checking of the diode or transistor to assure its suitability for the job. The simplest and perhaps most fool-proof test is to substitute elements in a carefully constructed breadboard circuit. Circuit performance may then be monitored through use of an oscilloscope, voltmeters and ammeters. A slightly more sophisticated version of this approach consists of combining the breadboard (modified for sample substitution of the semiconductor under test) with suitable panel mounted switches, bringing all important test points on the breadboard out to the monitoring instruments. With suitable allowances for varying circuit parameters and operating conditions, limits may then be set on the semiconductor under test.

While this in-circuit test is relatively simple, it is actually well suited to the most complex applications where it may be otherwise impractical to tie down individual parameters in a simple economical manner, but where overall performance may be easily checked. Furthermore, in difficult applications where selection of components or trimming adjustments are requirements this "in-circuit" test is very handy. Even for very small production runs, a "tester" of this type may be devised using some prototype or useable reject unit as a basis.

In performing tests on equipment incorporating semiconductor devices, it is important to use suitable power supplies. Of particular significance is the power supply output impedance, and often the variation of this output

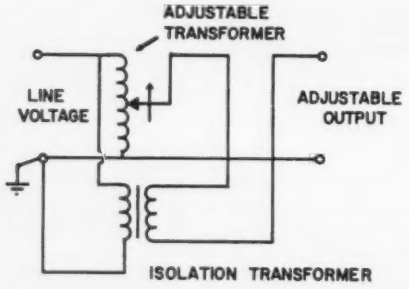


Fig 1 The above circuit provides a simple means of generating voltage transients of the order of tenths of a second at high power level. When applied to a rectifier, dc transient voltages are developed. The adjustable transformer is set by hand over a portion of its range, the interval of setting being roughly equal to the desired duration of the transient. This circuit permits testing of equipment for possible damage under these relatively long duration transients.

impedance over a wide frequency range. In switching equipment, line current transients of steep wave front are apt to occur. A spectral analysis of the current wave form reveals frequency components of many megacycles. In simple inverter circuits handling a hundred or so watts, current spikes may typically correspond to rates of change of millions of amperes per second. Even a microhenry of output inductance in the power supply can lead to voltage transients of the order of volts. Stray capacity can lead to resonant loops and vastly disturb the wave form of a "simple" d-c supply. In a particular instant, a transistorized inverter that operated very well in laboratory and production setups failed due to transistor breakdown when used in the field where power was supplied by a d-c generator. Here the leakage reactance of the generator windings interacting with the steep current spikes in accordance with the familiar formula

$$E = L \ di/dt$$

leads to severe like voltage spikes which were three times the amplitude of the steady d-c signal. In the application in question a hundred microfarad tantalytic capacitor across the line eliminated the problem.

In another application a high gain transistorized servo amplifier exhibited low frequency oscillations. This was traced to the power pack, in this case small batteries used in the test circuit. In the test rig the problem was solved by hanging about a thousand microfarads of capacitance across the d-c supply. In the specific system application a highly regulated transistorized power supply having less than 10 milliohms output impedance was employed.

For evaluation of semiconductor devices or instruments there is nothing better than a solid state, well regulated power supply. These devices with output impedance of the order of thousandths of an ohm recover from severe transients in less than 50 microseconds. Comparably excellent constant-current devices are available for testing semiconductor devices under constant current conditions. These must naturally be provided with safety devices to limit output voltages under open circuit conditions.

Where actual use-conditions require a less than ideal power supply, a highly regulated transistorized unit provides an ideal basis for simulating the actual supply, through addition of series resistive and inductive elements, and shunt capacative elements. By this means a most precise definition of power supply output impedance over the entire frequency spectrum is possible.

Sometimes, however, simulating a particular referenced military power supply is not so easy. For example, power supply voltage transients are often specified. In such an instance ingenuity in improvising a suitable circuit may be necessary. Fig 1 shows a particularly simple although crude circuit to check whether a piece of equipment can endure a specified line transient without damage.

Batteries frequently provide excellent ripple-free behaviour, may often be mounted close to the point of use, and, due to their simplicity, result in neat wiring and a minimization of pick-up and noise voltages. Batteries do not do well where heavy current drains mean overly frequent replacement, or where their output imped-

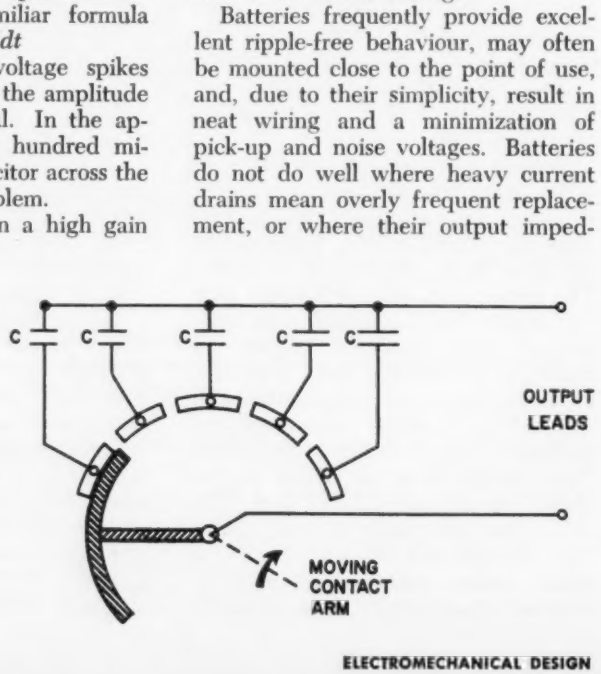


Fig 2 As the contact arm is rotated, capacitance is added or subtracted with relative smoothness, and with no interruptions to the circuit which might introduce undesirable transients.

ance may affect circuit performance. They are particularly handy as low-current bias supplies, where their individual isolation leads to circuit simplification.

Good power supplies, as explained above, are a vital part of any test equipment. Properly designed protective circuits will protect the supply from damage in the event of an output short circuit. Similarly, good output characteristics of the power supply eliminate the possibility of output transients leading to damage of the unit under test. Fuses are generally of little help, since damage occurs within a few microseconds.

ADDITIONAL TEST CONSIDERATIONS

Because semiconductor circuits are so sensitive to transients, test circuits should be set up in such a way that they minimize danger from this source. In particular, adjustments requiring switching of capacitors are apt to introduce difficulty. Fig 2 shows a good capacitor arrangement that permits adjustment without introducing circuit transients. Make-before-break switches used correctly will also minimize transients. Actually, it is necessary to know in advance which are the critical adjustments that are apt to cause transistor damage and to deal appropriately with them. Often, time-delay relays will sequence the application of voltages in somewhat analogous fashion to turning on filament voltage prior to plate voltage in vacuum tube circuits. It may be necessary to shut off power between adjustments. Wherever possible a smooth rather than discreet adjustment of critical parameters is recommended.

Circuit wiring is also an important consideration in semiconductor testing. Naturally, in R-C circuits, the usual wiring precautions relating to shielding, grounding, separation of power and signal leads, avoidance of ground loops, etc. must be observed. These precautions become increasingly important at higher frequencies in at least a direct proportion. In switching circuits involving pulses of nanosecond duration, where the signal spectrum extends to thousands of megacycles, suitable precautions must be taken. Stray capacitance and inductance in test circuit wiring can be particularly significant; this means first class components. Skin effect may be present in wiring, leading to high resistance in the leads to the very high frequency components of the signal. Test circuity should, of course, be kept as simple as possible. The "in-use" test circuit based upon a standard prototype unit where semiconductor devices are tested by the substitution method (as described previously) permits an

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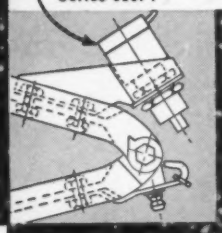

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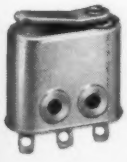

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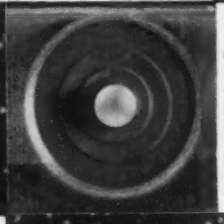

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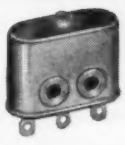

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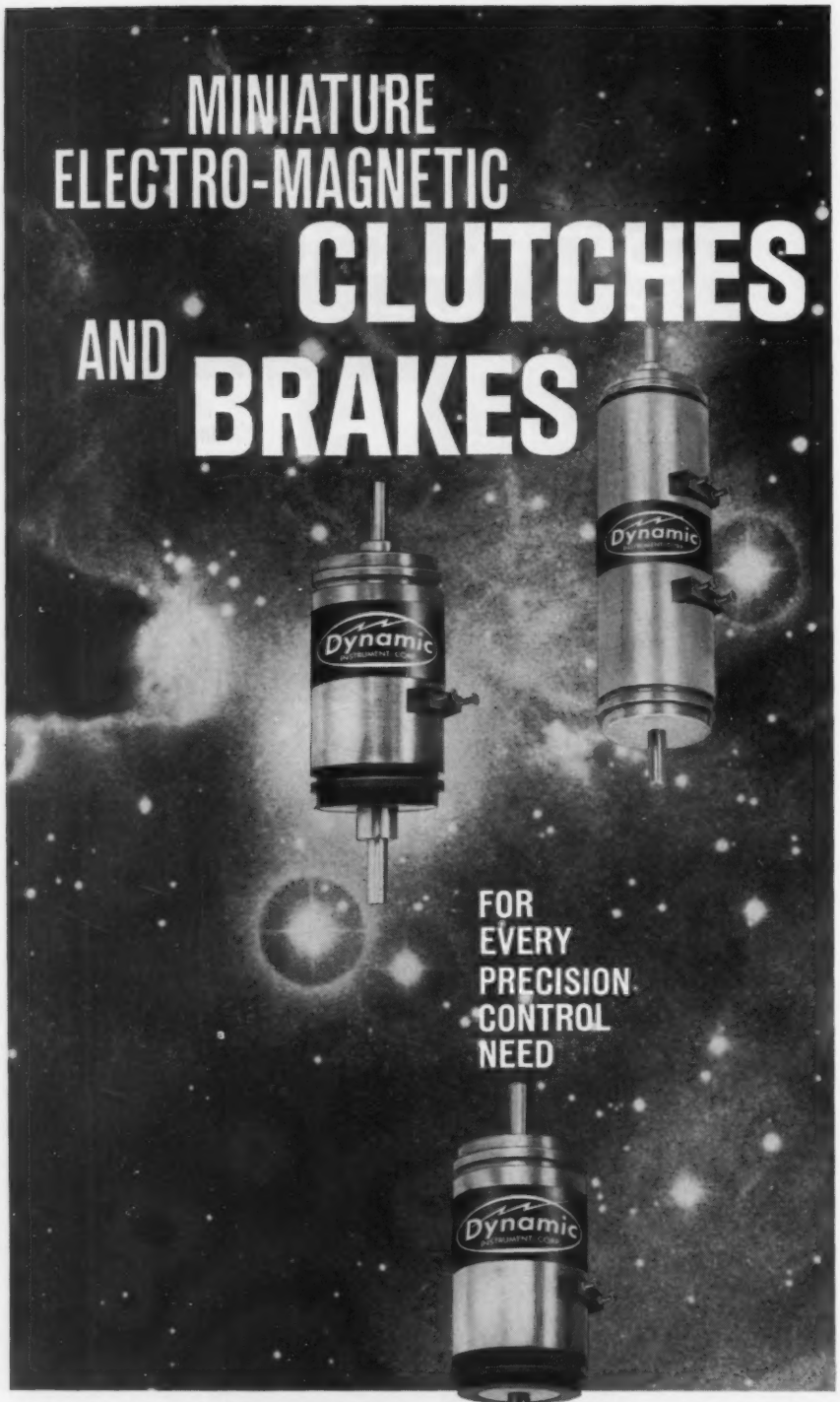

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With modern transistor and diode devices commonly rated at tens of amperes with intermittent peak values of many times the steady rating, wiring must be capable of carrying these heavy currents without significant ohmic drop. The problem is most severe in low voltage (6V, 12V) circuits where currents are high, and ohmic drops of the order of a volt constitute a large percentage of rated voltage.

Power supplies are available equipped to regulate voltage at an external point by means of two additional low current test leads brought out for connecting at the point in question. Thus, they may be conveniently located at some distance from the test circuit without introducing line ohmic drop difficulties.

Excessive temperature rise in the semiconductor device should be prevented during test. This may be difficult to achieve in the test circuit if heat sinking is sacrified in the interest of achieving an easily managed plug in test circuit. Furthermore, extreme test conditions may introduce heating which may be of only an intermittent nature in actual use. An ordinary fan directed at the semiconductor is a simple remedy. A simple push-button switch to provide circuit energization only for the brief instant necessary to test is often used. Where heating is critical, a timing device may be used to turn the circuit on for brief instants, but sufficient for observation of a pattern on a long persistent screen oscilloscope. Testing on a low duty cycle pulse basis is useful for checking operating points where excessive dissipation would otherwise occur. Pulse testing will be described later.

Often, particularly in high ambient temperatures, temperature rise of a transistor becomes a crucial limiting parameter. Consider a system operating in an ambient temperature of 85°C. If the transistor temperature rise at the collector-base junction is held to less than 15°C, then the 100°C temperature limit of commercially available germanium transistor is not exceeded, permitting a substantial cost reduction in comparison with suitable silicon units. (Of course, silicon units may be required for other than temperature limit reasons.) Frequently in testing out a system, a thermocouple anchored to the transistor base provides a most valuable indication of satisfactory performance. Often, cir-

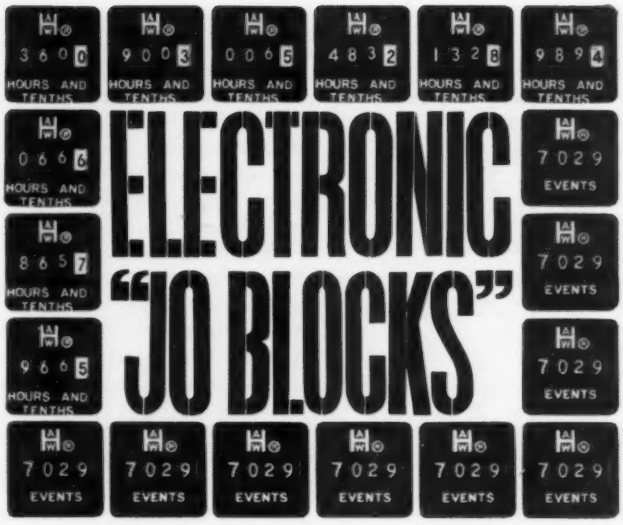
cuit parameters may be optimized to minimize transistor dissipation. An oscilloscope with vertical and horizontal plates connected to measure collector current and voltage as a Lissajous pattern provides additional data on collector junction dissipation. Even in complex nonlinear devices, an "optimum" Lissajous pattern will become consistently recognizable as corresponding to minimum collector dissipation, providing by this means a most convenient basis for adjustment. As a matter of fact, the oscilloscope provides the most valuable single tool for observing load lines, operating points, peak voltages, currents, etc. Many subtle aspects of circuit performance can be understood in terms of the distortion components of the oscilloscope pattern.

SEMICONDUCTOR PARAMETERS

In the preceeding paragraphs we have discussed how the semiconductor parameters influence system performance and how, by combining experimental and analytical techniques and reviewing requirements with the semiconductor manufacturer, we arrive at a set of values for parameters necessary to meet system performance requirements. By observing experimentally the maximum values of current voltage, and dissipation, for comparison with the manufacturer's specified limits, and determining marginal parameters, we select the parameters to be tested.

In this section, we describe briefly the semiconductor parameters of most interest. As previously stated, this part of the Digest is limited to consideration of low frequency parameters.

Testing low frequency characteristics of diodes consists basically of establishing the volt-ampere characteristics in the forward and reverse directions. These characteristics have the typical appearance of Fig 3. For relatively low power signals, ordinary d-c volt-ampere testing is quite suitable. Here the principal precautions are related to the relative amplitudes of the circuit currents and voltages. In the forward direction where high currents are encountered lead resistances must be held to an acceptable lower limit. Forward voltage drop must be measured by a separate pair of test leads directly on the diode as close to the body as possible so that contact drops (at the power connections) are not included. In the reverse direction where leakages are measured in microamperes, proper insulation is necessary to prevent additional external leakage. In both forward and reverse directions, meter impedances must be regarded with care to avoid their upsetting the ac-



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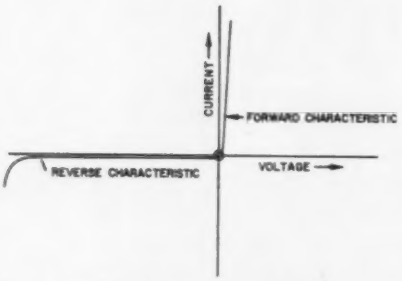


Fig 3 Typical diode characteristic; not to scale. Parameters of interest include the reverse leakage and break down voltage, and the forward voltage drop at some specified current.

curacy of the measurements.

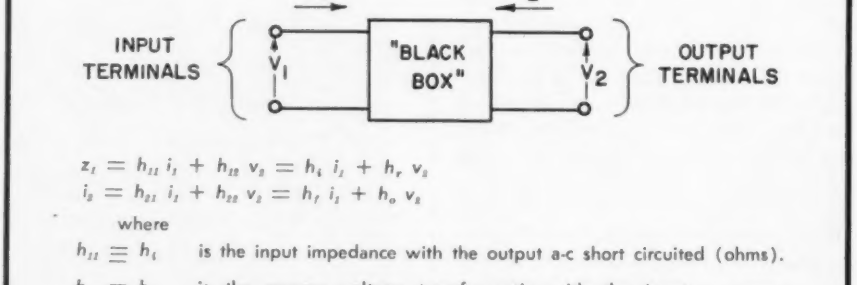
For simple qualitative testing, ordinary ohmmeter checks are useful to see whether or not a rectifier is in "reasonable" working order. Here there is some danger of damaging a unit by current overload from the meter in the diode forward direction. Excessive reverse voltages sometimes are introduced on the high ohm range.

A simple variation of the above system is to energize the diode from a low frequency a-c line, employing a series resistor to prevent damage when polarity is in the conducting direction. The resistor is chosen so that when supply voltage is at its peak with conducting polarity, current will be limited to a safe value. Supply voltage itself is selected so that reverse polarity peaks are capable of sweeping the peak inverse region of the rectifier. Voltage across the series resistor is a measure of circuit current. It is therefore possible to display the diode volt-ampere characteristic directly on an oscilloscope. This method is much more convenient than a d-c static test for viewing an entire characteristic quickly for comparison with that of a standard. A simple substitution test, combined with an error limit overlay pattern on the scope face, constitutes an extremely simple test scheme. Diode "in-circuit" testing is also feasible in many instances by this method.

However, the d-c test does provide a simple go-no-go method for checking a discreet number of test points. A maximum leakage current for a given inverse voltage, and a maximum forward drop for a given test current are the most commonly checked parameters.

In checking very high-current diodes, dissipation becomes an important factor. Proper heat sinking is essential. Momentary switching may be employed for point checking without excessive heat dissipation. Pulse generators providing about 5 msec pulses on about a 5% duty cycle are conviently used. Capacity of the power supply often is the important factor rather than diode dissipation, hence the value of momentary and pulse techniques.

Transistor parameters are commonly divided into small signal and large signal parameters, used as required for calculating transistor performance in particular circuit, and maximum voltage, current, and dissipation limits. Consider first the performance parameters. Using the "black-box" approach, we start by considering the transistor as a three (or four) terminal network, regardless of whether the circuit configuration is common emitter, common base, or common collector. The generalized 3-terminal network as shown in Fig 4 may be specified electrically in terms of four parameters. The figure presents the defining equations in terms of the so-called "hybrid" or "h" parameters, so called because they are defined from a mesh or voltage equation, and, a nodal or current equation. The black box is used to develop the parameters. Four measurements on the input and output terminals determine the four parameters. From these parameters, equivalent circuits representing transistor performance can be determined in a way analogous to the equivalent circuits used in the analysis of vacuum tube circuits. The equivalent circuits



$$z_1 = h_{11}\, i_1 + h_{12}\, v_2 = h_i\, i_1 + h_r\, v_2$$
$$i_2 = h_{21}\, i_1 + h_{22}\, v_2 = h_f\, i_1 + h_o\, v_2$$

where

$h_{11} \equiv h_i$ is the input impedance with the output a-c short circuited (ohms).

$h_{12} \equiv h_r$ is the reverse voltage transfer ratio with the input a-c open circuited (dimensionless)

$h_{21} \equiv h_f$ is the forward current transfer ratio with the output a-c short circuited (dimensionless)

$h_{22} \equiv h_o$ is the output admittance with the input a-c open circuited (ohms)

Fig 4 Three terminal network viewed as a black box, and defining equations for the "h" parameters.

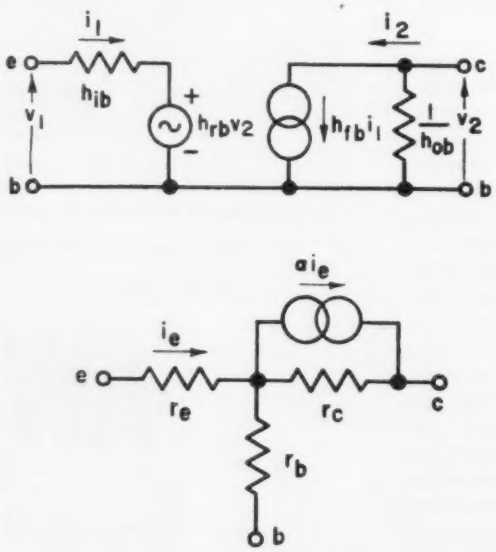


Fig 5 Equivalent circuits obtainable by straightforward network analysis from the black box equations.

5a Hybrid equivalent circuit corresponding to common base configuration.

5b Tee equivalent circuit derived from the hybrid equivalent circuit above.

can be manipulated in a variety of configurations. A simple Tee configuration is most useful in transistor analysis since it offers the most satisfactory correspondence between individual collector, emitter, and base terminals, and parameters and components of the equivalent circuit. Fig 5 shows how a common base equivalent circuit is derived from general parameters measured on a black box.

Actually, for a given transistor, the set of h parameters measured depends on the transistor configuration. However, since the Tee circuit of Fig 3 may be visualized, as desired, in the common emitter or common collector configurations, only one independent set of four parameters is possible. Formulas are available such that any four parameters establish the remaining parameters. Additional parameters corresponding to the actual equivalent circuit shown in Fig 5 provide more physical significance through correspondence with actual transistor behaviour. Table I adapted from the General Electric Transistor Manual conveniently relates these parameters for conversion of values.

We might well make a distinction between small signal and large signal characteristics. It is generally true of electronic devices, including semiconductor devices, that reasonable linearity occurs only over a limited portion of their characteristic curves; substantial departure from linearity occurs at very low and very high values of the electrical parameters. Thus, parameters measured as ratios of currents and voltages invariably change rapidly in the extreme nonlinear regions. If static curves are measured and the appropriate ratios of d-c quantities are taken, we have in effect a large signal parameter which may be plotted as a function of one of the electrical signals, which may be treated as an independent variable.

A common practice in a-c circuits is to employ d-c signals as bias, to set-up operative points in a linear region of the family of characteristic curves. A-c signals of relatively small amplitude may be superimposed on the d-c bias signals. As long as the a-c amplitude does not exceed the limits of the linear region, linear relations will exist between the circuit voltages and currents. Appropriate ratios of these voltages and currents establish the so-called small parameters. The small signal parameters are functions of the d-c bias point. Families of characteristic curves for a transistor permit the direct determination of large and small signal parameters with high accuracy. In particular, operation over wide signal ranges is best carried out by direct graphical investigation of the characteristic curves. Many skillful designers work directly on the transistor curve families whenever possible.

TABLE I

Approximate Conversion Formulae H Parameters and T Equivalent Circuit (Numerical Values are Typical for the G.E. 2N525 at 1 ma, 5v)

SYMBOL IRE	COMMON EMITTER	COMMON BASE	COMMON COLLECTOR	T EQUIVALENT CIRCUIT
h_{ie}	1400 OHMS	$\frac{h_{ib}}{1+h_{fb}}$	h_{ic}	$r_b+\frac{r_e}{1-\alpha}$
h_{re}	3.37×10^{-4}	$\frac{h_{ib}h_{ob}}{1+h_{fb}}-h_{rb}$	$1-h_{rc}$	$\frac{r_e}{(1-\alpha)r_c}$
h_{fe}	44	$-\frac{h_{fb}}{1+h_{fb}}$	$-(1+h_{fc})$	$\frac{\alpha}{1-\alpha}$
h_{oe}	27×10^{-6} MHOS	$\frac{h_{ob}}{1+h_{fb}}$	h_{oc}	$\frac{1}{(1-\alpha)r_c}$
h_{ib}	$\frac{h_{ie}}{1+h_{fe}}$	31 OHMS	$-\frac{h_{ic}}{h_{fc}}$	$r_e+(1-\alpha)r_b$
h_{rb}	$\frac{h_{ie}h_{oe}}{1+h_{fe}}-h_{re}$	5×10^{-4}	$h_{rc}-1-\frac{h_{ic}h_{oc}}{h_{fc}}$	$\frac{r_b}{r_c}$
h_{fb}	$-\frac{h_{fe}}{1+h_{fe}}$	−0.978	$-\frac{1+h_{fb}}{h_{fb}}$	$-\alpha$
h_{ob}	$\frac{h_{oe}}{1+h_{fe}}$	0.60×10^{-6} MHOS	$-\frac{h_{oc}}{h_{fc}}$	$\frac{1}{r_c}$
h_{ic}	h_{ie}	$\frac{h_{ib}}{1+h_{fb}}$	1400 OHMS	$r_b+\frac{r_e}{1-\alpha}$
h_{rc}	$1-h_{re}$	1	1.00	$1-\frac{r_e}{(1-\alpha)r_c}$
h_{fc}	$-(1+h_{fe})$	$-\frac{1}{1+h_{fb}}$	−45	$-\frac{1}{1-\alpha}$
h_{oc}	h_{oe}	$\frac{h_{ob}}{1+h_{fb}}$	27×10^{-6} MHOS	$\frac{1}{(1-\alpha)r_c}$
α	$\frac{h_{fe}}{1+h_{fe}}$	$-h_{fb}$	$\frac{1+h_{fc}}{h_{fc}}$	0.978
r_c	$\frac{1+h_{fe}}{h_{oe}}$	$\frac{1-h_{rb}}{h_{ob}}$	$-\frac{h_{fc}}{h_{oc}}$	1.67 MEG
r_e	$\frac{h_{re}}{h_{oe}}$	$h_{ib}-\frac{h_{rb}}{h_{ob}}(1+h_{fb})$	$\frac{1-h_{rc}}{h_{oc}}$	12.5 OHMS
r_b	$h_{ie}-\frac{h_{re}}{h_{oe}}(1+h_{fe})$	$\frac{h_{rb}}{h_{ob}}$	$h_{ic}+\frac{h_{fc}}{h_{oc}}(1-h_{rc})$	840 OHMS

In many cases, large signal parameters can be derived from the basic equations relating to current flow at the emitter and collector junctions. These equations, derived from principles of solid state physics, were very briefly introduced in a previous section of this Digest series. A future section will present them, with significant background material and applications, in more detail.

TRANSISTOR VOLTAGE RATINGS

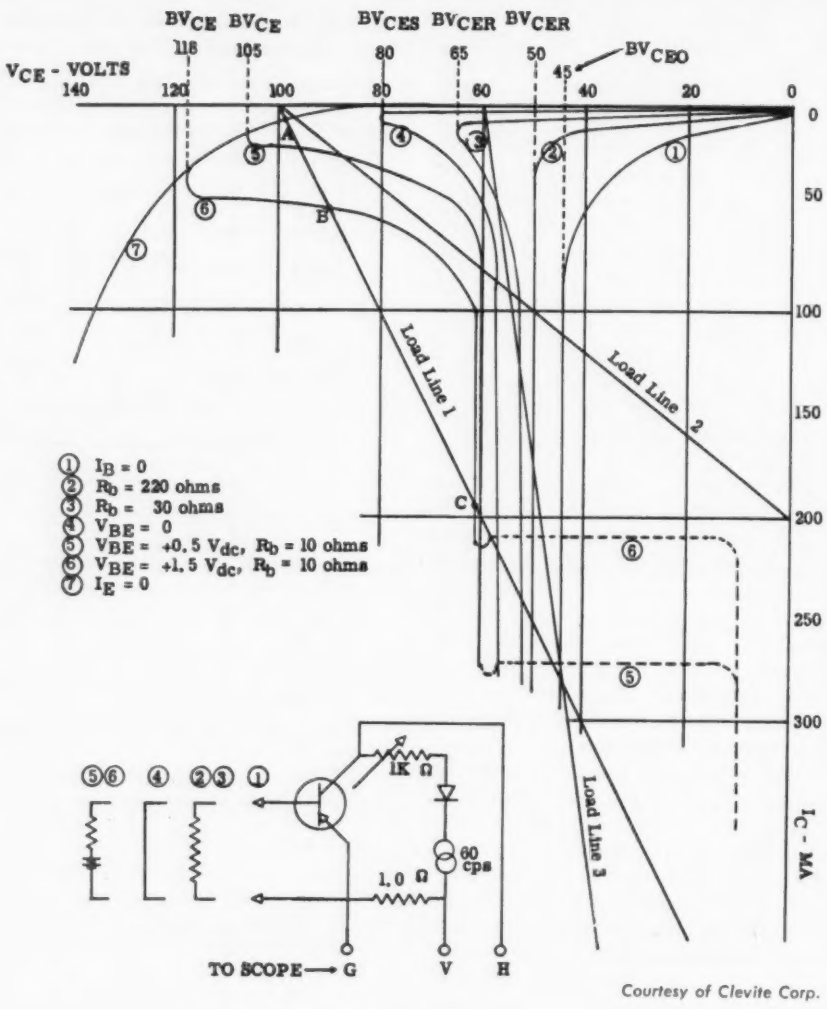
In comparison with diodes where the principle voltage limit rating is the peak inverse voltage, the transistor, being a more complex three terminal device, has a great variety of ratings, only some of which may be significant in a particular problem. As with the performance parameters, these voltage ratings are generally quite temperature dependent. Furthermore, the particular ratings of significance depend on the external circuitry. By presenting a great variety of voltage rating limits, corresponding to common transistor configurations, the transistor manufacturer allows the user to select those voltage limits which most nearly correspond to conditions in the "use" circuit.

Voltage ratings generally relate to a condition of use that is essentially

nonconducting. Thus a transistor with its reverse biased collector and its emitter circuit open will behave as a reverse biased diode, with a rating corresponding to the peak inverse voltage rating of a diode. Peak inverse voltage is actually a somewhat arbitrary figure, depending somewhat on the steepness of the leakage current versus inverse voltage curve. It is easily defined where breakdown is abrupt, as in a Zener diode, for example. Where breakdown voltage is marked by an increasing current but no abrupt breakdown point, peak inverse voltage may be defined as the point where leakage current reaches a prescribed value. This prescribed value is strongly temperature dependent, so test conditions must be spelled out. If leakage is measured from collector to emitter with the base open, the characteristic leakage current curve will be substantially different, values of leakage being much higher. Similarly, a different inverse collection to emitter characteristic is observed when emitter and base are shorted. Figure 6, from Clevite Application Bulletin No. 2, shows a variety of leakage characteristics for different transistor configurations. It is up to the design engineer to relate his circuit configuration to these test hookups to get the best idea of what voltage limits he must watch. With due regard to effects of temperature extremes, he then conservatively compares transistor ratings and his observed circuit voltages. Since high inverse ratings greatly increase transistor cost, it is best not to be too conservative.

Manufacturers also spell out current and power ratings. Exceeding these ratings may either lead to immediate destruction of the semiconductor device, or an excessive temperature rise leading eventually to destruction. Limits relating to temperature rise may be momentarily exceeded, the exact degree depending upon duty cycle. Since principal dissipation occurs at the collector junction, a plot of collector voltage vs current provides an indication of dissipation. Points of high voltage at very low current and vise versa do not indicate high dissipation. Figure 7 shows recommended limits for a Motorola Transistor.

Table II presents commonly used definitions of parameters applicable to transistor performance and rating, as formulated by Motorola.



Courtesy of Clevite Corp.

Fig 6 Collector breakdown characteristics

TRANSISTOR TEST CIRCUITS AND PROCEDURES

Material in this section is largely derived from Application Note 6-A by Delco Radio Division, General Motors Corp. Here we show basic circuits put together using common laboratory components for making direct measurements on transistors. In effect, most complex commercial test equipment is derived from these elementary circuits.

ELECTRICAL TEST PROCEDURES

Collector Diode Voltage Collector diode voltage, V_{CBO}, is measured using a constant value of collector current (see Fig 8). The constant current supply is adjusted for the desired maximum allowable leakage current with the switch in the closed position. The transistor is placed in the circuit, the switch is opened and the collector diode voltage is measured. A voltage limiter is provided to protect the operator and the transistor from high voltage. All measurements are made one-half to one second after the current has been applied.

Emitter Diode Voltage Emitter diode voltage, V_{EBO}, is measured using the same circuit as for the collector diode voltage, except that the emitter and collector are reversed in the circuit.

Open Base Open base voltage, V_{CEO}, is measured much the same as the diode voltages except that the current is higher. In the circuit shown in Fig 9, there will be approximately 240 ma with the switch open. The current will be different for each transistor, since it is dependent on the voltage drop across the transistor. The voltage limiter performs the same function as in the diode measurement circuit.

Shorted Base Shorted base voltage, V_{CES}, is measured using the same circuit used to measure open base voltage, except that the base is shorted

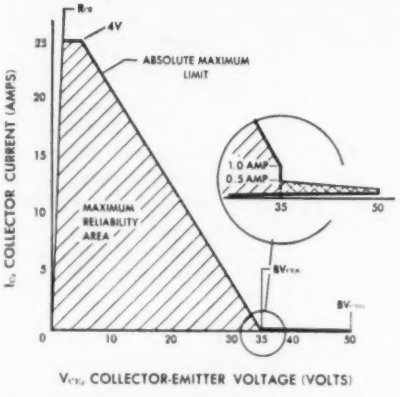


Fig 7 Recommended limits for a Motorola transistor. The maximum collector voltage and current are related by allowable dc power, transient conditions, and destructive voltage breakdown. The safe area of operation curves show a maximum reliable area of operation where destructive breakdown will not occur. The additional area as shown in the small detail drawings can be safely used with "L" shaped load lines.

to the emitter. An alternate method is to use pulsating current so that the current can be swept out to a high value, for example, to 300 ma. A transistor is placed in the circuit shown in Fig 10, the switch is opened, and collector to emitter voltage is observed on an oscilloscope. If there is any evidence of secondary breakdown the unit is rejected. Also the collector to emitter voltage should be equal to or greater than the voltage specified for the type transistor being checked.

Large Signal Current Gain Large signal current gain and base voltage are measured in the common base configuration as is shown in Fig 11. A constant of the desired magnitude is applied to the emitter lead by means of a 12 volt supply and a series resistance. For an emitter current, I_E, of 5 amperes, the series resistance would be approximately 2.4 ohms. Base current, I_B, is measured in the base lead and is divided into the collector current, I_C, to give the current gain B of the transistor for the common emitter configuration. I_C equals $I_E - I_B$, but I_B is small in comparison, therefore, I_C is approximately equal to I_E. For measurements made with large collector currents (5 amperes and above), care must be taken to

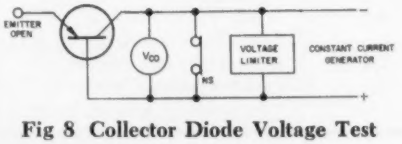


Fig 8 Collector Diode Voltage Test

reduce any voltage drop in the leads. Base voltage, V_{BE}, is measured from emitter (positive) to base (negative) and a voltmeter of 100,000 ohms/volt or greater is used. To reduce the power dissipation in the transistor, a constant voltage of only 2 volts is applied from collector to base. The transistor should be firmly attached to a heat sink.

Saturation Voltage Saturation voltage, V_{CE}, is measured using the circuit shown in Fig 12 with the transistor operated at a point where a further increase in base current gives no further increase in collector current. A rule of thumb that can be used is to measure the minimum base current needed to obtain the desired collector current and then double this base current to measure the saturation voltage. The output characteristics on the data sheets will show when a transistor is in saturation. A transistor is placed in the circuit and the base and collector currents are adjusted by varying R_1 and R_2. Care must be taken not to have a large voltage drop in the leads. Otherwise, an apparently high saturation voltage will be read, although much of it will be voltage drop in the leads. A voltmeter of 100,000 ohms/volt or greater sensitivity is used for this measurement. Saturation resistance is defined as the ratio of the collector to emitter voltage to the collector current.

Floating Potential Floating potential, V_{f1}, is the voltage appearing between the emitter and base (emitter open) with a given voltage applied between collector and base. In the circuit of Fig 13, the rated maximum collector diode voltage is applied and V_{f1} is read from emitter to base. The voltage will be low, probably about 0.3 volt. A meter having a high input impedance (10 megohms or greater) is used to measure this voltage. If a "chopper" type of dc voltmeter is used, care must be taken not to allow any 60 cycle pickup which could cause erroneous readings.

Thermal Breakdown All transistors are given a thermal breakdown test using the circuit shown in Fig 14. The transistor is mounted on a heat sink at 25°C ± 3°C with a thermal resistance of less than 0.3°C/watt between heat sink and transistor base. The specified voltage and current is applied to give the desired dissipation ($P = EI$). The transistor should not be damaged when operated in this circuit for three seconds. (The transistor will short out if it has poor thermal characteristics.)

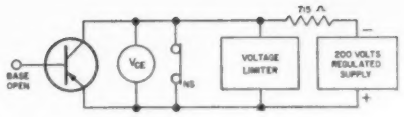


Fig 9 Open Base Voltage Test

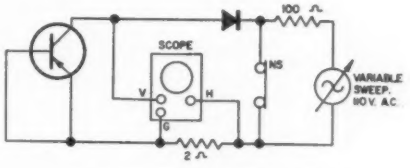


Fig 10 Shorted Base Test

Thermal Gradient Thermal gradient between transistor junction and transistor mounting base is measured using any method that depends on the variation with temperature of the collector cutoff current or the collector to base voltage with the collector biased in the forward direction. In the circuit shown in Fig 15a, the forward voltage drop of the collector diode is used. The voltage from collector to base with switches S_1 and S_2 in number 2 position is read first at 25°C junction temperature (T_J). The points are plotted on linear paper as shown in Fig 15b. The voltage varies linearly with temperature and decreases by approximately 1.8 millivolts per °C. This is the method used to calibrate the transistor. After transistor calibration, power is dissipated in the transistor by placing S_1 and S_2 in position 1. R_1 is adjusted until the desired dissipation in the transistor is obtained. The temperature is measured on the stud or base Tb of the transistor and when it reaches some

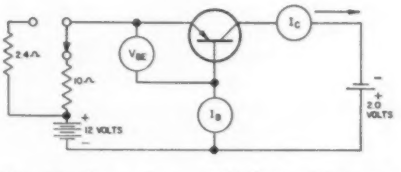


Fig 11 Base Current/Voltage Measurement Test

temperature (40°C, for example), the switches are placed in position 2 and the voltage (collector to base) is read instantaneously, using a scope. Taking this voltage and placing it on the line plotted on the graph, the junction temperatures can be determined. Using the formula below the thermal resistance can be determined as:

$$\theta(°C/watt) = (T_J - T_b)/V_2 I_2$$

TABLE II — Semiconductor Abbreviations and Symbols Generally Used by Industry

SYMBOL	MEANING
A	Ampere (ac rms or dc)
a	Ampere (peak)
B	Base electrode
BV	Breakdown voltage
BV_{CBO}	Breakdown voltage, collector-to-base junction reverse biased (emitter open)
BV_{CEO}	Breakdown voltage, collector-to-emitter junction reverse biased (base open)
BV_{CER}	Breakdown voltage, collector-to-emitter junction reverse biased (specified resistance)
BV_{CES}	Breakdown voltage, collector-to-emitter junction reverse biased (base shorted)
BV_{CEX}	Breakdown voltage, collector-to-emitter junction reverse biased (base-emitter back biased)
C	Capacitance and collector electrode
C_c	Internal collector junction capacitance
C (dep)	Depletion layer capacitance
C (dif)	Diffusion capacitance
C_{ib}	Input capacitance, common base
I_C	Collector current (dc)
I_c	Collector current (ac rms)
i_c	Collector current (peak)
I_{CBO}, I_{CO}	Collector cutoff current (emitter open)
I_{CEO}	Collector cutoff current (base open)
I_{CER}	Collector cutoff current (specified resistor from base to emitter)
I_{CERV}	Collector cutoff current (reverse voltage on base)
I_{CES}	Collector cutoff current (base shorted to emitter)
I_E	Average emitter current (dc)
I_e	Instantaneous emitter current (ac rms)
i_e	Instantaneous emitter current (peak)
I_{EBO}	Emitter cutoff current (collector open)
I_F	Forward current (dc)
i_F	Forward current (peak)
i_{Fr}	Forward recovery current (specified instantaneous value)
I_o	Output current (dc)
I_R	Reverse current (dc)
i_R	Reverse current (peak)
i_{Rr}	Reverse recovery current (specified instantaneous value)
I_Z	Average Zener current
I_{ZK}	Zener knee current
I_{ZM}	Zener maximum current
I_{ZT}	Zener test current
i_Z	Instantaneous zener current (ac rms)
K	Kilohm
L_c	Conversion loss
mA	Milliampere (average)
ma	Milliampere (peak)
mAac	Milliampere (ac rms)
mAdc	Milliampere (dc)

SYMBOL	MEANING
μA	Microampere (average)
μa	Microampere (peak)
C_L	Load capacitance
C_{ob}	Output capacitance, common base
C_{oe}	Output capacitance, common emitter
ΔV_Z	
E	Emitter electrode
f_{ab}	Common base small-signal short-circuit forward current transfer-ratio cutoff frequency (emitter input)
f_{ae}	Common emitter small-signal short-circuit forward current transfer-ratio cutoff frequency
f_{ref}	Reference frequency
f_{osc}	Maximum frequency of oscillation
f_{pg}	Power gain cutoff frequency
f_T	Frequency at which common emitter current gain is unity
G_b	Power gain (common base)
G_c	Power gain (common collector)
G_e	Power gain (common emitter)
g_M, g_{FE}	Static or D-C transconductance
g_m	Small-signal transconductance
G_M, G_{FE}	Large-signal transconductance
h_{fb}	Common base small-signal short-circuit forward current transfer-ratio
h_{fe}	Common emitter small-signal short-circuit forward current transfer-ratio (base input)
h_{FE}	Common-emitter DC short-circuit forward current transfer-ratio current gain I_C/I_B
H_{FE}	Common emitter large-signal short-circuit forward current transfer-ratio
h_{ib}	Common base small-signal short-circuit input impedance (emitter input)
h_{ie}	Common emitter small-signal short-circuit input impedance (base input)
h_{ob}	Common base small-signal open-circuit output admittance (emitter input)
h_{oc}	Common collector small-signal open-circuit output admittance (base input)
h_{oe}	Common emitter small-signal open-circuit output admittance (base input)
h_{rb}	Common base small-signal open-circuit reverse-transfer voltage ratio (emitter input)
h_{rc}	Common collector small-signal open-circuit reverse-transfer voltage ratio (base input)
h_{re}	Common emitter small-signal open-circuit reverse-transfer voltage ratio (base input)
$i_{(surge)}$	Surge current
I_B	Average base current (dc)
I_b	Instantaneous base current (ac rms)
i_b	Base current (peak)
mW	Milliwatt (max, ave, or rms)
mw	Milliwatt (peak)

SYMBOL	MEANING
NF	Noise figure
nsec	Millimicrosecond (nano)
Ω	Ohms
P	Power dissipation of all terminals (average total)
p	Power dissipation all terminals (peak)
P_b	Power dissipation of base, ave
p_b	Power dissipation of base (peak)
P_c	Power dissipation of collector (average)
p_c	Power dissipation of collector (peak)
P_d	Power dissipation of device
P_e	Power dissipation of emitter (average)
p_e	Power dissipation of emitter (peak)
PIV	Peak inverse voltage
Q	Transistor
$r'_{b'}$, $r_{BB'}$	Internal base spreading resistance
R_B	External base resistance
R_C	External collector resistance
R_E	External emitter resistance
$R_{(sat)}$	Saturation resistance
R_L	Resistance, load
T	Temperature
t	Time
T_A	Temperature, ambient
T_C	Temperature, case
TCBV	Temperature coefficient of breakdown voltage
t_d	Pulse delay time
t_f	Pulse fall time
t_{fr}	Forward recovery time
T_J	Temperature junction
t_p	Pulse time
t_r	Pulse rise time
t_s	Pulse storage time
θ_{EA}	Thermal resistance, case to ambient
θ_{JA}	Thermal resistance, junction to air
θ_{JC}	Thermal resistance, junction to case
V	Volt (dc)
v	Volt (peak)
Vac	Volt (ac rms)
V_{BB}	Base voltage (dc) supply
V_{BE}	Emitter voltage (dc) (base to emitter)
V_{CC}	Collector voltage (dc) supply
$V_{CE(sat)}$	Collector to emitter saturation voltage
V_{EC}	Emitter voltage (dc) (emitter to collector)
V_{EE}	Emitter voltage (dc) supply
V_{fe}	Floating potential
V_F	Forward voltage drop
V_O	Output voltage (dc)
v_o	Output voltage (ac)
V_{PT}	Voltage, punch-through
V_R	Reverse voltage (dc)
V_r	Reverse voltage (peak)
V_Z	Zener voltage
W	Watts (max, ave, rms)
w	Watts (peak)
Z_z	Zener impedance
Z_{zk}	Zener impedance, knee
Z_{zt}	Zener impedance, test

(Courtesy of Motorola Corp.)

COMMERCIAL TEST EQUIPMENT

The preceeding material covered the basic methods for checking transistor parameters, and for checking the absolute maximum limit of the electrical variables that will not cause permanent damage. Proper testing of semiconductor devices, either with special test setups, as previously described, or by using commercial test equipment, is of greatest importance in achieving good reliable performance at minimum cost. The importance of testing

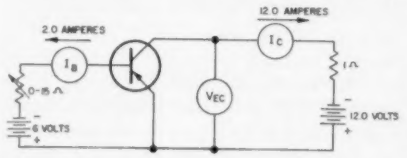


Fig 12 Saturation Voltage

is conveniently summarized in Table III taken from an informal technical paper "Reduction of Circuit-Developments Costs with Semiconductor Test Equipment," prepared by Owen Laboratories, Inc.

In this section, we describe briefly a variety of commercial testing devices applicable to the type of testing covered in this Digest: low frequency parameters of transistors and diodes.

To provide a useful order to this section we have classified the examples covered into three types: basic units, in-circuit units and more elaborate units. By basic units we mean low-

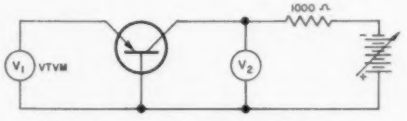


Fig 13 Floating Potential Test

cost instruments useful for servicing and quick testing in engineering laboratories. Most basic units can also be used for incoming inspection, quality control and sorting.

BASIC UNITS

For fast, accurate Beta testing, Hickok Electrical Instr. Co. has a dynamic tester, Model 870, with all ac Beta controls on one side and dc Beta controls on another. Common controls are placed under a meter and above a handy roll chart that contains set-up information for over 1150 transistors.

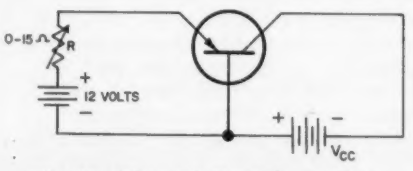
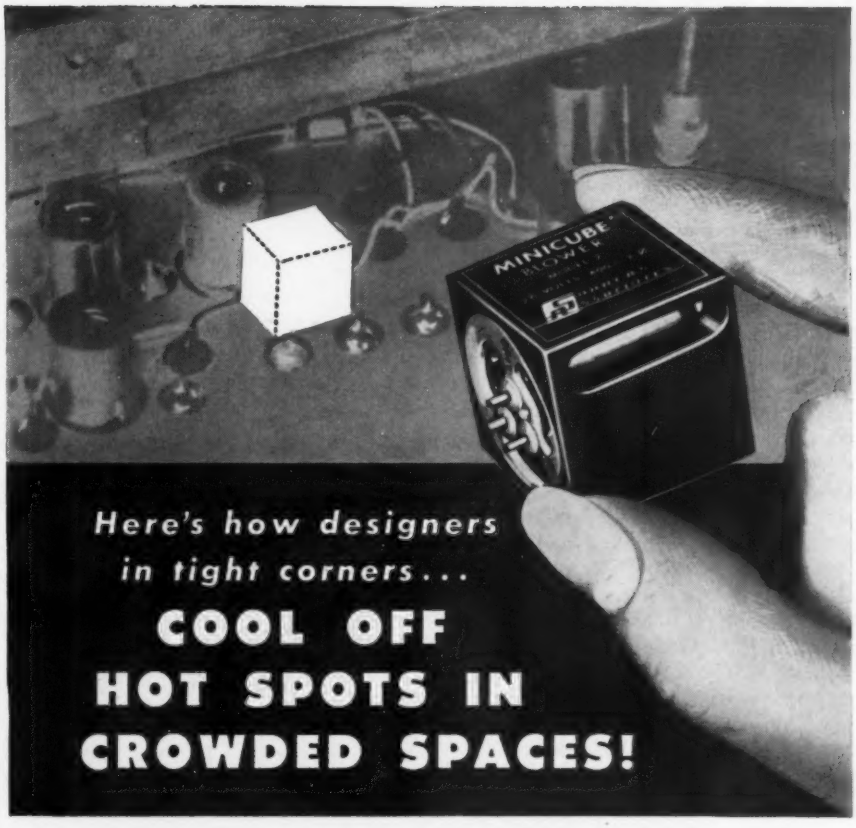


Fig 14 Thermal Breakdown Test



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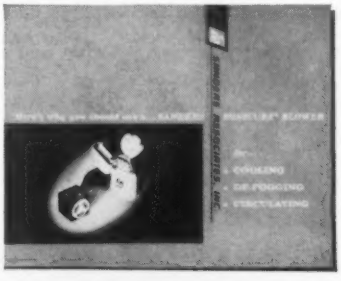

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COMPONENTS DIGEST

Figure 16 gives typical specifications of Model 870 and Fig 17 describes the unit's methods of measuring ac and dc Beta.

With an ac power supply generating small ac test signals, B & K Mfg. Co.'s Model 160 Tester measures Beta directly to within ±3% accuracy. All transistors are automatically biased to standard 1ma collector current. Instrument gives direct meter reading on shorted, open and leaky junctions and tests gain and leakage current of power transistors permitting accurate matching for audio circuits. Dc power supply voltage is variable and metered. B & K Model 160 is priced at approx. $69.95.

A very elementary tester for servicing, Triplett Electrical Instr. Co.'s Model 690-A tests leakage and dc Beta for all low and medium power transistors. It also checks forward and leakage current of diodes. Dc Beta tests vary from 5 to infinity and leakage test range from 0-600 microamps. The price of Triplett's Model 690-A is approx. $29.50.

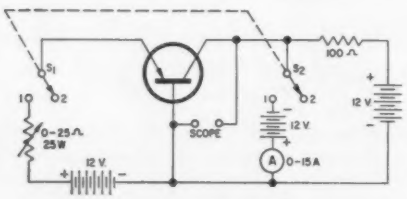


Fig 15a Thermal Gradient Test

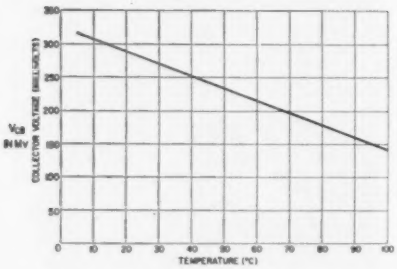


Fig 15b Thermal Gradient

A somewhat more elaborate instrument, by Triplett, is their Model 2590 that tests, under simulated operating conditions, Beta, I_{CBO}, I_{CEO} for both power and signal transistors. It also tests for shorts and leakages plus checking diode leakage and forward currents. Specification of this model, priced at approx. $54.50, are given in Fig 18.

Model ATI0C, a more costly instrument (approx. $385), by Electronic Research Associates, automatically indicates ac values of the Alpha and Beta parameters as a function of emitter and collector bias. In addition, it tests for Alpha and Beta cut-off and values of Alpha-Beta at high audio frequencies. Accurate measurements of transistors with both high and low values of current ratios can be made. Specifications include: Alpha range, 0-1.0; Beta range, 0-50, 0-100, 0-200, 0-400; accuracy, 5% full scale; cut-off range, 1 mc max. (external oscillator).

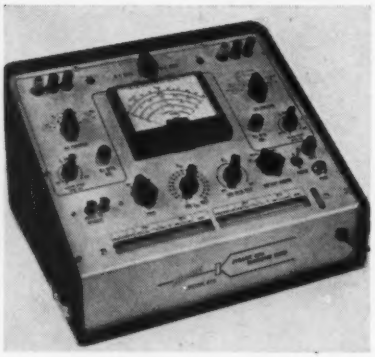
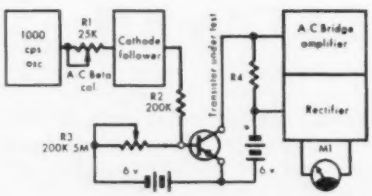


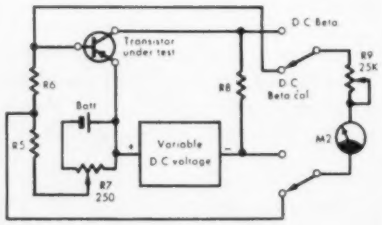
Fig 16 Hickok Electrical Instr. Co.'s Model 870 measures ac and dc Beta at specified current and voltages. Measures I_{cbo} in the following ranges: 0.100 μa, 0-1 ma and 0-10 ma — with a variable V_{cb} of 0.100 volts. Beta ranges: 0-100 and 0-300, extendable to 600 by reducing ac test signal to 2½ μa. Beta test collector current is completely variable, 0-2 amps — permitting satisfactory Beta measurement on power transistors rated 5 amps or more. Hickok Model 66K-type meter has sensitivity of 100 μamps with internal resistance of 1000 ohms and is protected by a silicon diode type SD91 that conducts and by-passes any excess current that could cause damage. Both ac and dc Beta are well within 5%.

IN-CIRCUIT TESTERS

Measuring ac Beta with an accuracy of 5%, Hickok Electrical Instr. Co.'s Model 1890 tests all small and medium power transistors and diodes in circuits. Hickok's method of neutralizing circuit impedance, before tests are made, prevents inaccuracies. Type of Beta tests performed, small ac signals superimposed on a variable dc forward bias level, are under Class A conditions and to manufacturers' test specs. Test procedure, broken down into 5 steps, is triggered by a function selector that switches the test circuitry



AC BETA TEST DIAGRAM



DC BETA TEST DIAGRAM

Fig 17 Simplified schematics depict the ac and dc Beta test circuits of Hickok Electrical Instr. Co.'s Model 870 Dynamic Tester. For ac testing, a phase shift oscillator generates an ac test signal which feeds an impedance converter, cathode follower stage. An ac Beta calibration control *(R1)* adjusts test signals; calibration set line on meter face is set to 1v peak-to-peak. During the ac Beta test, a 1000 cps signal produces a 5-μamp current flow in the base of the transistor under test. *R3* forward biases base to desired collector current, in most cases 1 milliamp. Calibrated 5-μamp test current circulated in the base causes a current flow of $I_b \times$ Beta in the collector. To meter this I_c current, *R4* is connected in series with the collector. AC signal developed across *R4* is amplified by the ac bridge amplifier, rectified and fed into the metering circuit. Comparing collector to base current determines dc Beta. In the dc schematic, *R6* is a monitoring resistor, *R5* a protection resistor and *R7* is employed to vary input current from 120 μamps to 400 milliamps. Resistors connected in series with base and collector are fixed in a known ratio. Voltages developed across these resistors are proportional to current flowing through them. The higher the dc Beta, the larger the voltage developed across *R8*. Since the dial is marked as a function of dc Beta, it permits direct reading. Adjusting potentiometer *R9* to vary sensitivity of the metering network locates calibration point. To monitor dc Beta, metering circuit connects across *R8*. Since the value of *R8* is selected in known ratio to the value of *R6*, the meter reading is the dc current ratio or dc Beta of the transistor under test. Nickel cadium batteries are used as collector and base current sources and are kept in a fully charged state with either a high rate or trickle charge current. Power on-off switch is independent of the charging network and need not be on to charge the batteries. Trickle charge may be left on indefinitely without damaging the batteries.

Fig 18 Meter ranges of Triplett's Model 2590 Transistor Tester are: 0-1 ma for signal transistor I_{CEO}; 0-100 ma for power transistor I_{CEO}; 0-500 microamp for signal transistor I_{CBO}; 0-1 ma for power transistor I_{CBO}; and 5-100 Beta range; also shows on GOOD-?-BAD scale. No roll chart or special technical data is required with this unit; the only information needed to make a test is the transistor type.

to the desired configuration in sequence. Although Model 1890 was designed to test in the circuit, it will also test out of circuit with equal accuracy.

TABLE III

Six Cost Saving Applications of Semiconductor Analyzers. Each application precedes actual circuit development, thus eliminating time consuming uncertainties.

1. Determination of transistor characteristics under operating conditions differing from those given on the manufacturers' specification sheets.

2. Test of transistors, diodes, controlled rectifiers, etc., that are to be used in experimental circuits, in order to be sure that they are good, typical, units. Similarly, test of units that are being used, to see that they remain undamaged and capable of giving the desired result.

3. Selection of maximum and minimum units, in order to check circuit operation over the widest range of semiconductor performance that may be counted.

4. Determination of the distribution of gain, leakage, and other values in semiconductor shipments as received, so that realistic compromise between circuit performance and semiconductor cost can be made.

5. Salvaging of transistors, diodes, zeners, etc., that have been used in the engineering laboratory, for further experimental use.

6. Much more rapid education of laboratory personnel in the ways of transistors, and their variations with current, voltage, and temperature.

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COMPONENTS DIGEST

Model 219B tester, by Sierra Electronic Corp., measures Beta in the circuit and tests I_{eo} out-of circuit. Accuracy for in-circuit is ±20% for external loads above 500 ohms, for out-of-circuit it is ±10%. Beta test ranges are 1-4, 3-12, 11-40, 30-120, approx. to 300; I_{co} ranges from 0-50, 0-500 microamps. This instrument sells for approx. $275.00.

A simple, compact, low-cost ($19.95) dynamic transistor checker, made by Seco Electronics, gives a fast indicator lamp, go-no-go check at practical collector currents from 5 ma on small transistors and up to 50 ma or more on power types, either in or out of circuit. Safely identifies NPN or PNP types – excellent for matching similar types. No set-up is required, and the visual indication to the output signal is the end result of dynamic current gain in an actual operating circuit.

Testing transistors, diodes, or rectifiers (germanium or silicon) in or out of circuit, Molecular Electronics Model ICT-100 measures salient characteristics and detects shorted, opened, or

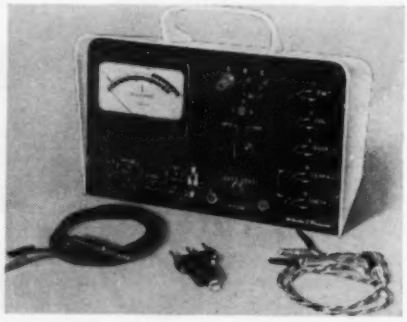

Fig 19 In-circuit or out of circuit tester of transistors and diodes, Model ICT-100, from Molecular Electronics.

leaky devices while they are in circuit. It also measures the characteristics of a replacement semiconductor without the necessity of soldering the device into the circuit. No charts of semiconductor specs or a knowledge of previous device history are needed to operate ICT-100. The compact, portable device, priced at $195, is shown in Fig 19.

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By using a unique varying duty cycle testing method, Baird-Atomic's

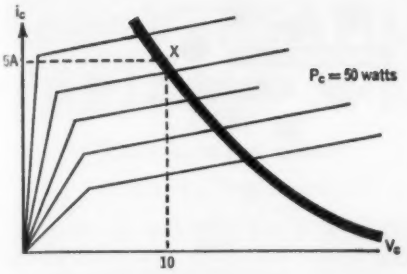

Fig 20 Typical power transistor C-E set of collector characteristics illustrates how Baird-Atomic Model NC-1 uses a variable duty cycle method of testing to permit measurements at power levels higher than the transistor could survive if normal dc methods were used. To measure dc current gain at point *X*, a steady state voltage of 10V and a current of 5 amps is required. If conventional dc biases were used, 50 watts of input power would have to be dissipated by a large heat sink or auxiliary cooling. In testing this transistor by Baird-Atomic's variable duty cycle method, a peak collector voltage of 10 volts and suitable base drive to produce collector current pulses of 5 amps peak are applied. For the current pulses 100μsec. wide at 1/60 sec. repetition, the average power is: $P = (V_c)\ (I_c)\ T/T$. For this example: (10) (5) $(100 \times 10^{-6})/(1/60)$ = 0.3 watt.

Model NC-1 permits measurements at power levels higher than the transistor could survive if normal dc methods were used. Also, less stress is put on the transistor. Under optimum conditions, the power fed into the transistor is but 1% to 3% of the power used with conventional dc current, according to the company. Instrument applies suitable pulse drive signals to the transistor under test and then peak detects the resulting current pulses so that they have the same measuring value as steady state dc. This technique is

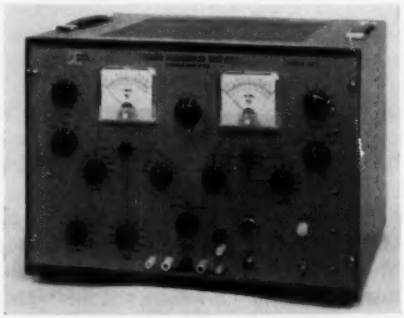

Fig 21 Baird-Atomic's Model NC-1 is a direct-reading variable duty cycle, medium and high power transistor test set. Peak pulse method of testing permits measurements at high power levels without large heat sinks or auxiliary cooling. Instrument tests at 750 watts maximum with 50 amps max. current or 250 volts max.

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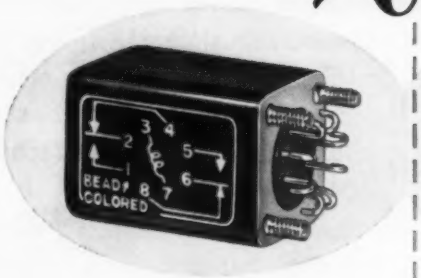

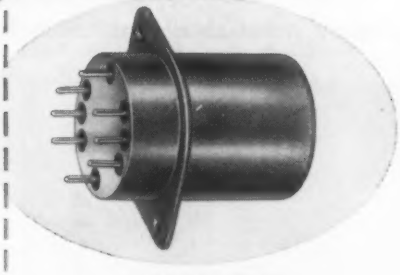

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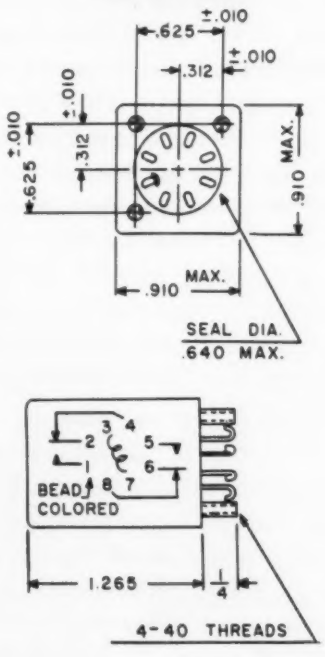

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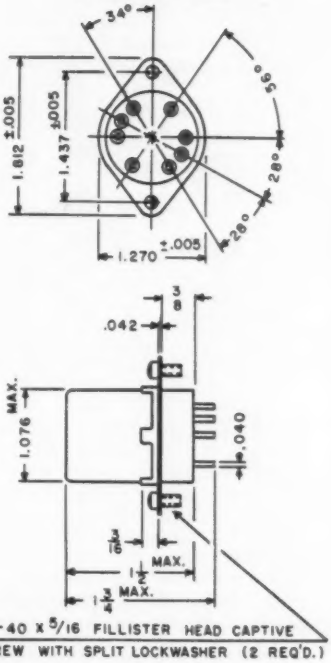

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vernistat® design report

Information on Vernistat a.c. potentiometers for design engineers

HIGH LINEARITY, LOW QUADRATURE, HIGH INPUT-OUTPUT IMPEDANCE RATIO, AND WE'RE THINKING SMALL!

The new Size 9 Vernistat® a.c. Potentiometer follows the trend to the compact! It has small dimensions but considerable stature. And biggest news of all, there's been a major price shrinkage! The reason?—new design and improved manufacturing techniques.

Specifications of the Size 9 Vernistat prove that good things do come in small packages. These new units provide high input-low output impedance ratios, low quadrature (phase shift), ten-turn accuracy with continuous rotation, and a host of other features. To put numbers to these claims: the Size 9 has an input impedance of 60K ohms with an output impedance of only 160 ohms; 0.2 mV/V quadrature; ±0.05% terminal conformity; and 0.01% resolution. Size is important here too — only 0.875 inches in diameter and 1.85 inches long.

Those of you who previously have been kept out of the Vernistat fold by size and price considerations can do great things with this new model. Why don't you investigate soon the improved results that Vernistats can give to the analog, servo and computer circuits you design.

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WHAT IS A VERNISTAT?

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The Vernistat is an excellent component for precision servo and computer circuits where high accuracy combined with reliability is required. The Vernistat may be used with great advantage as a:

Servo Follow-up Element — where high gain and accurate response are important, the Vernistat provides high loaded terminal linearity, high resolution, and low quadrature.

Computer Element — the Vernistat may be simply cascaded to perform function multiplication, because of its high input-output impedance ratio.

Data Transmitter — or readout device in analog equipment such as navigation systems, fire control computers, and Doppler radar systems.

vernistat division
PERKIN-ELMER CORPORATION
768 Main Avenue, Norwalk, Connecticut

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COMPONENTS DIGEST

illustrated in Fig 20 and specifications for Model NC-1 are described in Fig 21.

Baird-Atomic also has a curve tracer, Model MW-1, that displays characteristic curves for PNP and NPN transistors in either common base or common emitter configurations. Operational range includes the highest maximum voltages and currents and lowest impedances: 30 amps and 300 volts, 450 watts max.; impedance (minimum observed) 0.001 ohm up to 10 megohms. Overall accuracy is better than 2½%.

Testing unit that sets up transistor for viewing patterns on a scope is Curtiss-Wright's (Electronics Div.) Model TCT-2 Transistor Curve Tracer. It displays collector voltage – collector current (output) curves, common emitter or common base connection. Designed for use with any standard dc oscilloscope, Model TCT-2 displays one curve at a time by manual selection, or a fine curve family. Emitter-base voltage for selected input currents may be measured using an external dc meter to characterize the input curve. Ranges include: V_c, 0-60 volts peak; I_c, 0-50 ma; I_b or I_e, four steps of 10 microamps, 50 microamps or 1 ma per step.

Designed primarily for application laboratory work, Curtiss-Wright's PTT-1 Power Transistor Test System provides complete dc characterization of transistors with ranges up to 20 amperes. Patch panel arrangement permits unusual flexibility of operation and connection of special circuit configuration as needs dictate. Readout of breakdown voltages, leakage currents, emitter floating potential and saturation voltage measurements, and a simultaneous display of input and output voltages and currents are provided on precision panel meters. Unit is packaged in two 42" racks for standard bench mounting.

Owens Labs produces a number of test sets, typical of which is their Model 300, a self-contained portable instrument for checking medium and large power transistors and rectifiers at high power levels. Collector currents to 30 amps and potentials to 300 volts are available. Voltage and current curves are generated for oscilloscopic display. With an accessory converter, gate characteristics and anode drop of silicon controlled rectifiers can be determined within the in-

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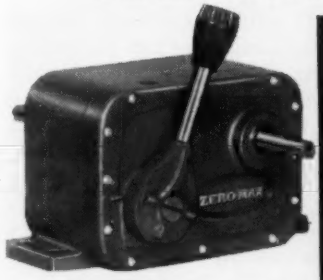

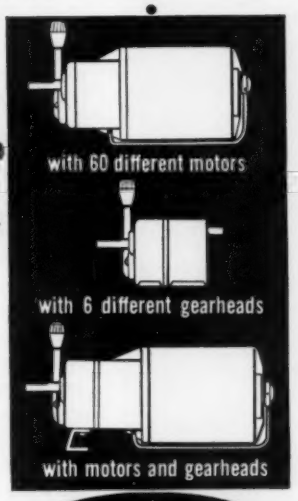

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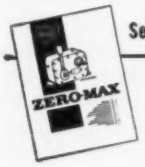

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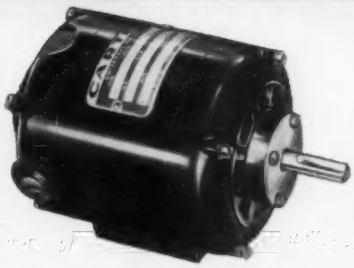

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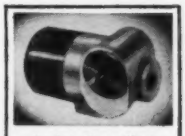

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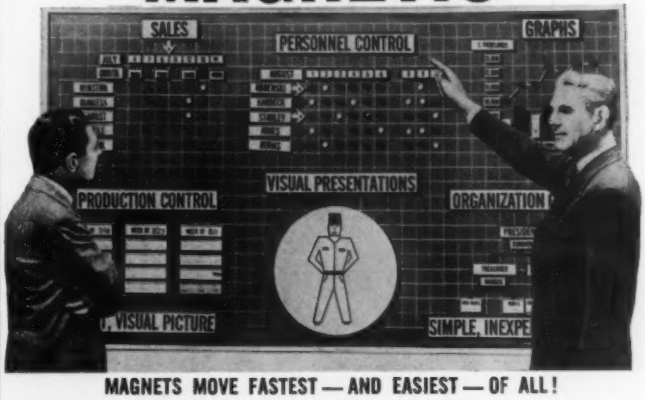

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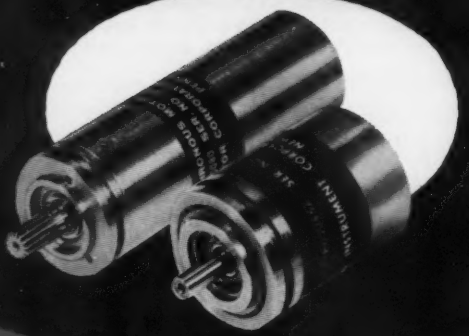

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Kollsman's new Size 8 Synchronous Motors have a high "precision to ruggedness" ratio . . . were specifically designed for small space and light weight. Ungeared unit weighs only 1.25 oz. ■ These subminiature units are ideal for high reliability, high-performance applications in computer systems, camera drives, scanning devices, and other missile/avionics equipment. ■ Measuring only .960" length (ungeared), 2 5/32" (geared), the new Size 8's feature a synchronous speed of 8,000 rpm with a 400 cps input: source voltage is 55 volts; total power input is 5 watts; pull-in torque is .025 oz. in. Gear boxes available in ratios from 5:1 to 20,000:1. ■ You can now design your equipment or system smaller and better with a Kollsman Motor. Kollsman sales engineers are ready to assist you whatever your motor design needs. Take advantage of their experience which covers over 1,000 motor designs . . . which will save you time and money.

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CIRCLE NO. 57 ON INQUIRY CARD

COMPONENTS DIGEST

strument's ratings. Converter includes a peak voltmeter that can be used for measuring saturation voltage of power transistors. Model 300 consists basically of two power supplies, one producing up to 30 amps collector current of pulsed waveform, the other a similar but lower current base supply. Synchronous chopper peak voltmeter compares base-input and collector currents to give H_{fe} measurements.

Another model, from Owens, Type 310 is a sophisticated portable semiconductor test set for accurately measuring operational parameters of small and medium transistors, diodes and Zener diodes under constant current and voltage conditions to 100 ma and 30 volts. Leakage and reverse current test potentials range to 600 volts. Owens believes that the combination of their types 300 and 310 covers the great majority of all test requirements.

Testing under actual operating conditions, Wallson Associates' Model 170A Dynamic Rectifier Analyzer tests any semiconductor rectifier with any combination of ratings up to 20 amps and 1000 volts peak, without the need for bulky external load resistors. It measures average reverse current from 1 microamp to 50 ma in four ranges, average forward current ranges from 0.5, 1, 2, 5, 10, and 20 amps, average forward voltage drop — 0-1, 0-5 volts. Unit has provisions for monitoring parameters on an oscilloscope.

Orbitec Corp.'s Model T3A-2 provides an oscilloscopic display of a complete plot of Beta vs I_c from 0 to 500 ma peak current at fixed frequencies of 1 kc and 10 kc. Provision is also made for obtaining plots out to 1 mc by means of an external generator. Separate graticule marked with the collector current coordinate on a logarithmic scale is available for replacing the conventional linearly marked graticule. Accuracy is 5%, exclusive of oscilloscope error.

Model TDT-200A Transistor-Diode Tester, from Transistor Electronics Corp., tests transistors, diodes, and rectifiers in the manner in which they are used in computers and industrial electronic applications — dc circuitry under a wide range of currents and voltages. The components used have been specifically chosen to provide a long trouble-free life and still allow the production of the instrument at a moderate price (approx. $325). TDT-200A has provision for correcting for

ac line voltage variations over the range of 105 to 125 volts.

Instrument is accurate to approximately 3% of the full scale meter readings.

Tektronix has devised an extremely versatile tool for the evaluation of transistors and diodes. In their popular Model 575, an adjustable sweep voltage of adequate current capacity is available as a collector drive. A staircase generator provides an adjustable series of base currents in steps, so that an entire family of transistor characteristics may be viewed on the integral oscilloscope. Both large signal and small signal parameters as well as breakdown voltages are derivable from the scope pattern.

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Tektronix	761
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WORTH FILING

Synchronous Motors

Construction and operation of the 395 different types and models of synchronous motors are described in a 20-page bulletin. Speed torque curves, dimensional drawings, wiring diagrams are included on units ranging from 1/2000 to 1/6 hp.

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Diminutive Electromechanical Devices

Several of our editors feel that this 60-page handbook, designed to assist the engineer in selection and application of electro-magnetic clutches/brakes, mechanical clutches, torque indicators, torque standards and multi-speed transmissions, contains exceptionally clear, useful and practical information on topics therein.

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Pulse Transformer Kit

Six ferrite core pulse transformers in standard 7-pin miniature plug-in bases offer over 20 different inductance values for simplification of breadboard design. All have turns ratios of 3 : 2 : 1, with secondary and tertiary rise times of less than 0.1 microsecond. Insulated to withstand potentials of 500 volts, the units operate over a temperature range from −55 to +105°C. Hamilton Watch Co., Lancaster, Pa.

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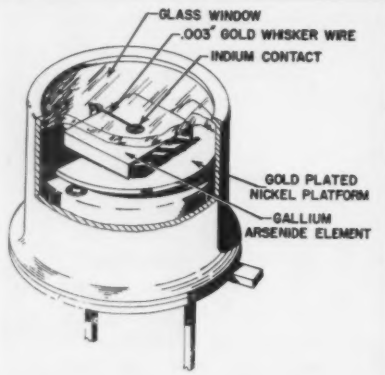

Photovoltaic Detector

Developed by engineers at the Lansdale Div. of Philco Corp., a gallium arsenide photodetector, providing high sensitivity for both visible and near-infrared regions, is designed for the 0.4 to 0.9 micron region, having a peak sensitivity at 0.85 microns. Philco has placed the single crystal photovoltaic detector in a small, rugged TO-18 case, used commonly as a transistor package. "This detector", Gen. Mgr. C. H. Sutcliffe explained, "unlike conventional photo diodes, does not suffer serious sensitivity degradation when exposed to daylight and replaces photo multipliers in providing 1 to 2 orders of magnitude of increased responsivity in the near infrared region." Operation up to 120° has shown no loss in detector sensitivity, he said. The device exhibits virtually no microphonism and can withstand massive radiative overloads without permanent damage. The small size may make possible the combination of a solid state amplifier and photo detector potted in one single block no larger than a matchbox. Applications include celestial body sensing, missile tracking, satellite attitude control and guidance, computer readout and numerous industrial process controls. $100 each for sample quantities.

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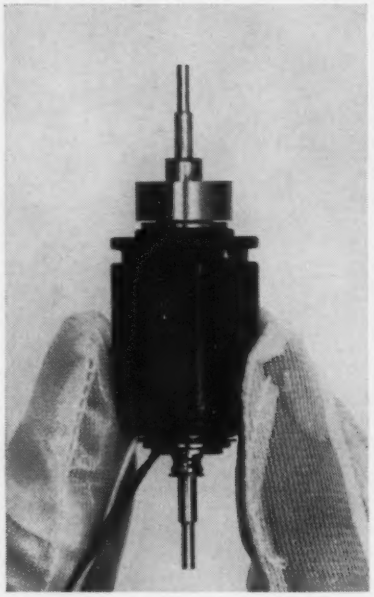

Miniature Slow Speed Drive

Combining the advantages of smooth operation with high shock capacity under vibration (20g at 10-2500 cps) and extreme compactness, a new miniaturized slow speed drive consists basically of a drive motor and a small gearless speed reducer. Designed for light duty applications such as potentiometers, slip rings and synchros, present applications include timing devices, telemetering systems and oscillating ball bearing drives for gyro gimbals. Units are made on order with size 10, 11 or 12 motors. Input-to-output speed ratios are available within the range of 25:1 up to 5,000:1. The drive is not a substitute for conventional gear head motors because of backlash and limited torque output. Barden Corp., Danbury, Conn.

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60 CPS Fan

Well-known Propimax 2 fan is now available as a 60 cps model. Measuring slightly over 3" in diameter, 1½" deep, and weighing 6½ oz, the fan moves 17.5 cfm under free delivery conditions. Materials and finishes meet most applicable military specs. Power required is 0.05 amperes at 115 volts, under free delivery conditions. Physical and aerodynamic symmetry permits reversing of air flow by merely turning end-for-end. Mounting is by means of servo-ring; rpm at free delivery is 3250. Rotron Manufacturing Co., Inc. Woodstock, New York.

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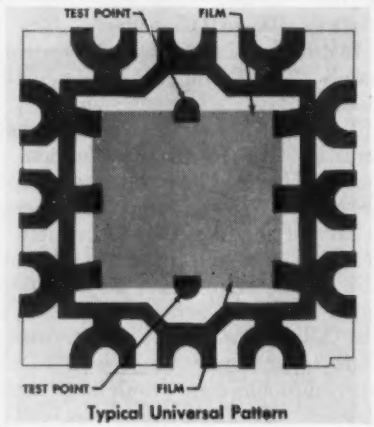

Typical Universal Pattern

"Do-It-Yourself" Resistor

Wafer type "universal" film patterns permit user to tailor the resistance between desired terminals to the required value using some expedient method of film scoring or cutting. Basic (uncut) values range from 100, 500, or 1000 ohms per square (± 25%). Films on each side of the wafer can be the same uncut value or different values. This metal-film type resistor on a thin ceramic wafer (0.310 square by 0.010" thick) can be used with capacitor, inductor and semi-conductor elements to form a tiny cube-like assembly for performing an entire circuit function. Ohmite Manufacturing Co., 3677 Howard St., Skokie, Ill.

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Voltage-to-Frequency Converter

Wide range, highly linear voltage-to-frequency converter has solid state circuit that converts a given voltage into a corresponding frequency with better than 0.1% linearity and with stability approaching that of good crystal oscillator. Virtually the only variable in the circuit is temperature drift which is held to 0.2%/°C from 0 to 50°C without the need for temperature stabilization. Model is a fully-encapsulated, four transistor unit measuring 3¾" by 2¾" by 1". It empioys no equalizers or non-linear control elements. Operating at a nominal center frequency of 600 kc, it provides frequency deviation of ±100 kc from the nominal with better than 0.1% linearity. Only a slight impairment in linearity is incurred when the same unit is deviated from 200 kc to 1.2 mc with control voltages from −0.75 v to −5.5 v. Unit has a number of different control and instrumentation applications. High frequency devices such as frequency modulators and wireless microphones, can make use of the square wave outputs' strong harmonic content. Neshaminy Electronic Corp., Neshaminy, Pa.

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Remote Angle Counter

Rotation of input shaft in a new remote angle counter produces in-line, digital display of angle at a remote location. Unit replaces conventional synchro torque transmitter. Readout lights replace the torque receiver indicator.

Advantages include: 0.1° accuracy, standard size servo mounting, no amplifier, translator, or any auxiliary package needed, and unit operates on dc or any ac frequency. The counter can also replace conventional angle counters used in computers, servo systems, antenna pedestals, and gun mounts for the purpose of providing alignment and trouble-shooting aid as well as operator orientation. Theta Instr. Corp., Saddle Brook, N. J.

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Pressure Transducer

Withstanding 100g acceleration with little error, a 1.7 ounce, low pressure potentiometer transducer operates in 0-10 to 0-350 psia ranges. An aneroid capsule connected to the inlet pressure fitting detects pressure changes which are transmitted as proportional linear movement through a metallic belt linkage to the wiper of a precision potentiometer. Pressure media are contained within the aneroid capsule and therefore isolated from the electrical component enabling operation in any deleterious atmosphere without adverse effect. Manufacturer claims exceptional high immunity to vibration without fluid damping for the unit and its performance characteristics are said to make it ideal for use in critical environments. High level dc or ac signal output can be used with amplification for control or telemetry circuits. Servonic Instruments, Inc., Costa Mesa, Calif.

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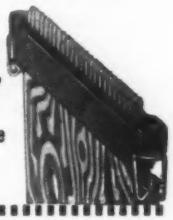
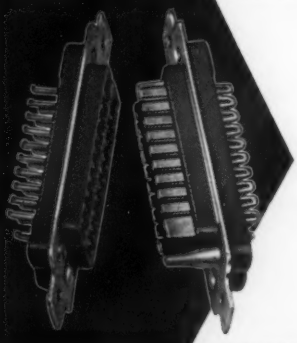


Locking Device (optional)



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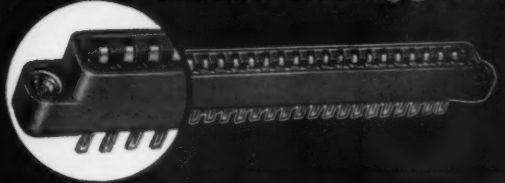
"RIGHT ANGLE" MALE CONNECTORS with pin termination

threaded mounting grommets



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Methode Electronics, Inc.

7447 West Wilson Avenue
Chicago 31, Illinois

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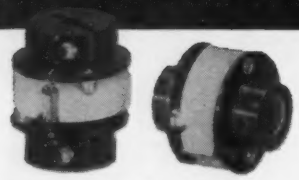
TIC

MINIATURE
FLEXIBLE COUPLINGS

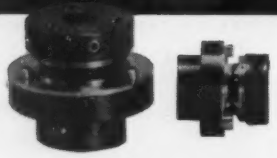


FEATURE • No Backlash • Compactness and Lightweight • Accommodate both lateral and angular misalignment • Choice of types offer clamping or set-screw hubs

Type MPC-1 consists of two flanged aluminum hubs and nylon or Delrin discs with V-grooves that are displaced 90° with each other. Discs are fastened with stainless steel springs loading ball pivots against V-grooves. Dimensions ⅞ x ⅞ in.
Type MPC-2 has two cylindrical aluminum hubs, each with two ball pivots attached. Hubs are attached to a pair of flexible phosphor bronze discs which hold and load the ball pivots. Dimensions ¾ x ½ in. Both types have range of bores to accept shafts from .120″ to .250″ and meet MIL-E-4970 and withstand −80° to 200°F and shock to 100 G.

TIC

ADJUSTABLE
SLIP CLUTCHES



FEATURE • Adjustment over a wide torque range • Compactness and lightweight

Type ASC-1 is ⅞ x 1″
Type ASC-2 Miniature is ⅝″ x ⅝″
Both are constructed of aluminum hubs, Delrin* on stainless steel clutch plates and stainless steel hardware. These rugged, high performance clutches are friction units to protect components against excessive or inertia shock loads. Range of bores to accept shafts from .120″ to .250″. These clutches meet MIL-E-4970 specs.
For details on couplings or clutches write

* ® DUPONT T.M.

TIC
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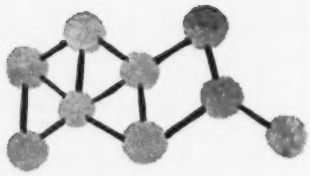
by David Bandel
Staff Columnist
Associate Technical Director,
TRACERLAB, INC.



MATERIALS

Rechargeable fuel cell, Fuelox, developed by Ionics, Inc., shows promise of important commercial and military applications because of its high power to weight ratio. Outputs of 40 watts per pound have been demonstrated and it is claimed that outputs up to 10 times higher can be attained with continuing improvements. The Fuelox cell is unique in having operated at almost 100% conversion efficiency, although for most applications about 50% efficiency is more practical. Operating on hydrogen gas and a solution of bromine compounds in water, the cell can be recharged by any conventional electrical source, including solar cells for satellite instrument power. A pioneer in the use of ion exchange membranes for desalinating water by electrodialysis, Ionics has developed a special plastic membrane which is used in the cell.

***Commercial low temperature fuel cells** are also available from a Japanese manufacturer. Low pressure hydrogen and oxygen from air is the fuel in a carbon electrode system. Sodium hydroxide solution is the electrolyte. Initial unit offered, consisting of 10 cells developing 1 volt at 3 amp with a total weight of 11 lbs, is claimed to be 70% efficient.*

New development in thermocouples, announced by the Nanmac Corp., makes possible more accurate surface or in-well temperature measurements. Thermocouple body is fabricated from the same material as the wall of the vehicle or vessel under test. This reduces the errors introduced by thermal property differences of the materials in the thermocouple and the test material. Thermal elements are composed of flat ribbon wires insulated by thin sheets of mica sandwiched between a split tappered pin and pressed into the thermocouple housing. With the exception of the thin ribbon thermocouple elements and mica insulation, all other material in the sensing tip is made of the same material as the container wall. Thermocouples have been fabricated from diverse materials as Plexiglass, Teflon, asbestos phenolic, graphite, copper, molybdenum and tungsten. Temperature range can vary from −320°F to over 5,000°F with operating pressures up to 3,000 psi.

***Subminiature capacitors operable in the range of 400°F,** in the development stage at Radiation Research Corp., represents a unique application of Teflon as the dietectric material. Teflon tape, first metallized on both sides to deposit a conducting thin film, is exposed to TFE monomer in the vapor state and the TFE vapor polymerized by a glow discharge to coat the metallized surfaces with a thin layer of Teflon polymer. This process produces a uniform, pin hole free coating, it is claimed. Experimental 50 and 100 v. capacitors with space factors less than half of those presently available will be offered soon for evaluation. A similar approach to an integral conductor-dielectric material has been available from American Machine and Foundry. AMF process, based on coating thin aluminum foil with Teflon polymer dispersion and fusing the Teflon in a tower furnace, produces coatings less than 0.1 mil on each side.*

Mylar polyester film has many unique characteristics. It has a high tensile strength, for plastics, excellent dielectric properties and reasonably high temperature limits of performance. A new use for Mylar is in driving belts for instruments and mechanical equipment. At the Goddard Space Flight Center, polyester tapes have been used as drive belts for tape recorders and other satellite instruments. These belts have shown good fatigue resistance and high stress tolerance. Small diameter pulleys can be used due to the high degree of compliance in the thin films. Belts ½ mil in thickness have been applied to shafts as small as 40 mils in diameter with reasonable service life. This permits development of high reduction drives in miniature electromechanical equipment. Heavier belts, 5 mils or more, can be used in larger machine drives. Coefficient of expansion of the materials used closely approximates those of magnesium, and aluminum alloys and heat treatment increases torque capacity. Surface charge that develops, normally a nuisance in most applications, helps retain the belts in position and keeps them from rubbing during idling.

New Daystrom Series 319 Potentiometers Can Be Adjusted In Seconds After Ganging

It can be done. 24 cups of the Daystrom 319 Series potentiometers ganged within six inches. *Most important,* phasing of individual cups can be accomplished after installation, and with no interference to adjacent cups. Results: finite adjustments • many hours and dollars saved in installation costs • re-phasing in a matter of seconds!—■—The Daystrom 319 Series is ideal for multi-channel applications. Exclusive Daystrom design techniques result in unusual stability to shock, vibration, and other severe environmental influences. The 319 is rated at 2 watts in *still air,* operates over a range of −55°C. to 150°C, is available in resistances from 100 ohms to 200 kilohms, and meets or exceeds all applicable MIL Specs. Send for further data.

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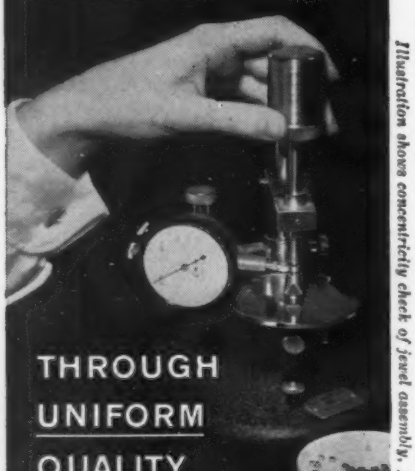
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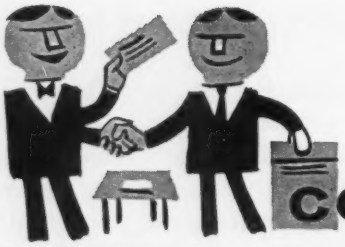

CONTRACTS

"Fifteen zoology department people put bands on 15,850 bats during two nights of work at Eagle Creek near Morenci, Ariz." We congratulate them for their nerve and high batting average but we never dreamed that there were 15,000 bats in the whole country never mind finding 15,850 at one little old creek in just two nights; so there is a bat for every belfry. The banding of the "flying blind mice," for studying short range migration, is the beginning of a project, supported by a $17,987 Navy contract, based on the use of a micro-miniature radio that will attach to the bat's back so movements can be followed with a receiver. Howard A. Baldwin, who is designing the radio at the University of Arizona's Dept. of EE, indicated that a dime-size instrument weighing two to three grams will be possible for short transmission ranges. "Much of the work, the first year," he said, "will be concerned with development of special power sources and tracking equipment." UA's Dept. of Zoology (the people who braved "Bat Day at Eagle Creek") hope to find secrets of long distance navigation through radio tracking of the home range, homing ability and migration routes of the bats. Again, our hats are off to them, but not for long.

Research on self-organizing pattern recognition devices will be performed by the Computer Products Div. of Laboratory for Electronics, under a contract by the Aeronautical Systems Div., Wright-Patterson Air Force Base. Based on the known ability of the human eye to "follow" an object when determining the character of that object, a mosaic of photocells, capable of redirecting its movements in response to commands from within its recognition system, will comprise the "pickup". During initial phases, the photocell "eye" will randomly scan a pattern, breaking it up into a succession of less complex, more easily recognized parts, hypothesize as to object's identity, then direct itself to those parts of the object which will allow confirmation or rejection of the hypothesis. Although this dynamic device may be more sophisticated than necessary for objects such as printed letters and numbers, it is expected to have significant applications for more complex patterns such as handwriting or cloud formations.

"It's going to be a barren monotonous place." That which has inspired so many love songs, poems, and other forms of emotional outbursts has been so characterized by John De Nike, program manager of Martin Co.'s lunar transport study, analysing what conditions on the moon would be like. Martin holds a contract with NASA to study a complete earth-moon transport system covering three basic missions: lunar landing and immediate return for three men, 30-day stay on the moon for three men, and permanent moon base for 10 - 12 men. On the moon, man will need vehicles for exploration; the state of near-vacuum, De Nike explained, will probably lead to new vehicle design. Moving parts which need lubrication would have to be enclosed; vacuum would deteriorate rubber tires quickly. Martin drawing boards are therefore envisioning such wheel modifications as wire brushes or rolling spheres. Other equipment, including the space ship, should be able to maneuver to a certain degree if only to change position; for this, Martin's solution appears to be stilts which would support the vehicle and operate like mechanical walking legs.

BRIEFLY:

Submarine batteries:	$7.5 million to Electric Storage Battery Co., from the Navy.
Missile systems:	$29.6 million to Avco from the Air Force.
Air navigation equipment:	$8 million to ITT from the Navy.
Electronic countermeasure simulators:	$11.8 million to Reflectone Electronics from the Air Force.

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NEW DATA SHEETS

Most of these data sheets contain complete specs, mounting configurations and other important details associated with the application of the products described. For your free copy of the data sheets listed on this page, enter the appropriate number of the item on the Inquiry Card.

Antenna Design 926

Intended as a reference for antenna design engineers, data card contains specially derived graphs and charts that show, in simplified form, the principal sizes, distances, and values of most of the required set-up data for recording antenna radiation patterns. Commonly used systems of nomenclature, fast calculating equations, and size-frequency coverage of illuminating antennas are presented. Blaine Electronetics Inc., Van Nuys, Calif.

Altitude Test Chamber 918

For testing electronic and hydraulic components, a test chamber has an ultimate altitude of 200,000 feet and a temperature range of −100 to +240°F. Pull-down time to −90°F is 45 minutes while heat-up time to +240°F is 15 minutes. Evacuation time to 150,000 feet takes 30 minutes. Cold-wall liner maintains low temperature simultaneously with high altitude. Industrial Refrigeration Co., Inc. Culver City, Calif.

Rotary Actuated Switch 902

High temperature, hermetically sealed switch has a rotary linkage-lever actuator for use in locations where actuation and release may ordinarily be impaired by ice and dirt. This switch operates effectively in applications involving radical temperature variations from −65° to +600°F. Detailed construction and characteristics are given. Minneapolis Honeywell Reg. Co., Freeport, Ill.

Air Rotary Actuator 904

Built in response to design demands for speed, compactness, and overall system simplification, pneumatic rotary actuators complete a 90 degree stroke within 30 to 40 milliseconds. Low air displacement requirements of the miniature high speed units allow system size reductions in compressor capacity, tubing filters, valves and regulators. Piston action is converted into rotary motion on the output shaft through an internal combination of bearings and an inclined plane principle. Ledex, Inc., Dayton, Ohio.

Pressure Transducers 910

Glossary of pressure transducer definitions and descriptions of various units covering the range of 0-300 through 0-5000 psig are contained in data sheets. Model 300, originally designed as a small pickup for use in the measurement of rocket nozzle pressures, has survived rocket firings many times and, as a consequence, been selected for many applications, outside the rocket field, demanding an extremely sturdy pickup. Standard Controls, Seattle, Wash.

Wire Wound Resistors 931

Resistors meet MIL-R-26C with an allowable 350°C hot spot well above the customary 250-275°C in resistors of this type. Units carry full power even at 125°C. Minimum resistance range is 0.1 ohm, and maximum is 20 to 175K ohms. Temperature coefficient averages less than ±25 ppm/°C. International Resistance Co., Philadelphia, Pa.

Miniature Translator 917

Used in the measurement of displacement, pressure or acceleration in airborne or laboratory telemetry systems, a new miniature dc-in dc-out translator has reflex multiple-function circuitry, good dynamic frequency response, high power output, extreme regulation, minimum ripple, good stability and optimum coefficients of temperature. DC power regulation of added loads, such as heaters and filaments, is within same high regulation of translator itself, ±0.1%. Physical Sciences Corp., Pasadena, Calif.

Versatile Relays 916

For open, plug-in or printed circuit applications, general purpose relays are offered in standard contact arrangements up to 3PDT. Detailed coil data and contact nomenclature are provided in two tabular presentations. Relays pass a 1000 volt AC Hipot test between all elements and they operate continuously in ambient temperatures of −45 to 75°C for dc coils and −45 to 55°C for ac coils. Line Electric Co., Orange, N. J.

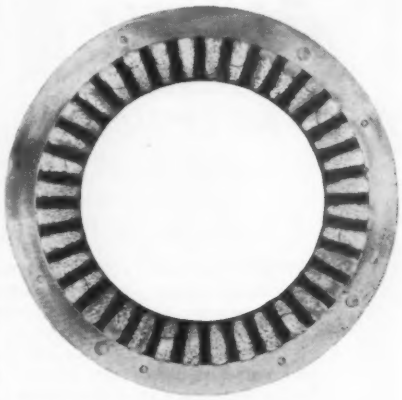
High-Speed Digital Resolver 912

Within less than 200 microseconds, digital resolvers take two 10-bit inputs representing Cartesian coordinates and convert them into two 10-bit numbers representing polar coordinates. Three built-in registers X, Y and θ perform the conversion function. Polar to Cartesian coordinate conversion can be accomplished in an analogous manner by driving the θ register instead of the Y register to zero. Accuracy is better than 1% of full scale. Computer Control Co., Inc., Los Angeles, Calif.

Rotary Solenoid Drive 915

Designed to remotely control any "Blue Line" switch regardless of contact development and configuration, rotary solenoid drives operate in single steps, continuous steps, or as master-slave for automatic operation. Described are operating principles, methods of control, applications, and modular construction of the unit. Simple twist-to-lock bayonet principle eliminates the need for special tools in assembly. American Solenoid Co., Inc., Union, N.J.

breakthrough



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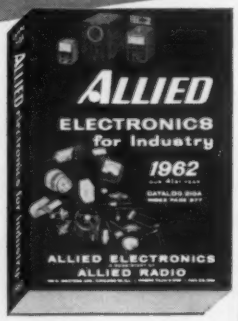

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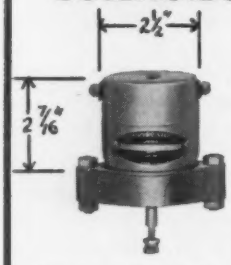

These solenoids are ruggedly constructed, having a life expectancy of over 2,000,000 operations at a rated capacity of 10 lbs. pull. They are available with ½, 1 and 1½ inch stroke.

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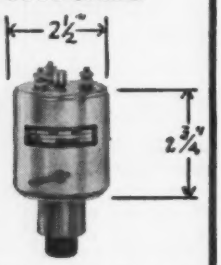

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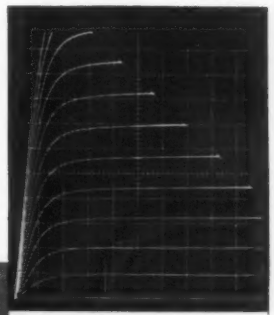
TEKTRONIX TRANSISTOR-CURVE TRACER

INVALUABLE TOOL FOR EVALUATING SEMICONDUCTOR DEVICES



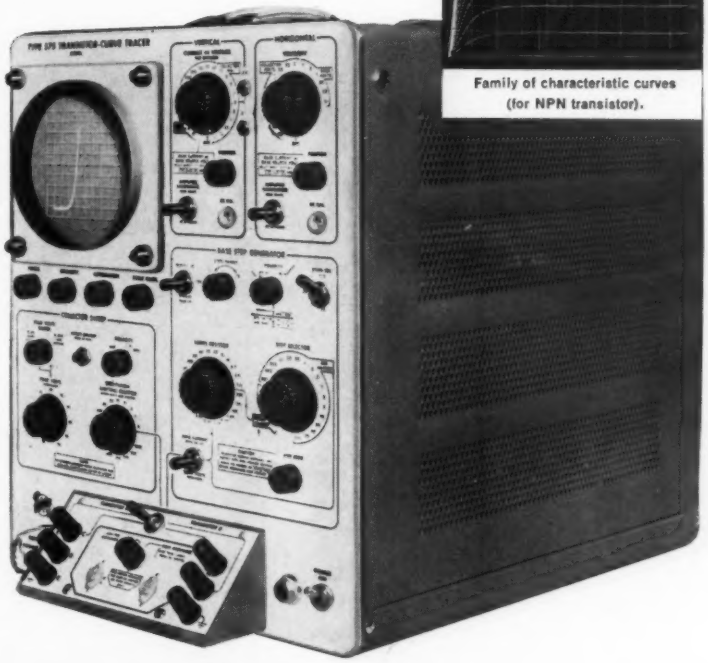
Family of characteristic curves (for NPN transistor).

The Type 575 provides 20-ampere collector displays (10-ampere average supply current), two ranges of collector supply (0 to 20 volts, 0 to 200 volts), and 2.4-ampere base supply (positive or negative base stepping).

With a Type 575, you can plot and measure 7 different transistor characteristics. You can display 4 to 12 curves per family—with input current from 1 microampere/step to 200 milliamperes/step or input voltage from 10 millivolts/step to 200 millivolts/step—in repetitive or single-family presentations. You can select either common-emitter or common-base configurations.

Add a Type 175 Adapter and you extend the range of collector displays 10 times and the range of base supply 5 times.

You can also test diodes under a wide variety of conditions and observe waveform characteristics on the 5-inch crt with a high degree of accuracy.



Type 575 Calibrated Displays

Vertical Axis—Collector Current, 16 steps from 0.01 ma/div to 1000 ma/div. Pushbuttons are provided for multiplying each current step by 2 and dividing by 10, increasing the current range to 0.001 ma/div to 2000 ma/div.

Horizontal Axis—Collector Voltage, 11 steps from 0.01 v/div to 20 v/div.

Both Axes—Base Voltage, 6 steps from 0.01 v/div to 0.5 v/div. Base Current, 17 steps from 0.001 ma/div to 200 ma/div. Base Source Voltage, 5 steps from 0.01 v/div to 0.2 v/div.

Type 575 Transistor-Curve Tracer $975

HIGH-CURRENT ADAPTER

For measuring high-powered semiconductor devices which exceed the current capabilities of a Type 575, ask your Tektronix Field Engineer about the Type 175 High-Current Adapter. Not intended for separate use, the Type 175 depends upon the circuitry and crt of a Type 575 to provide *200-ampere collector displays, three ranges of collector supply, and 12-ampere base supply*—for calibrated displays with Collector Current on the Vertical Axis and either Collector Voltage or Base Voltage on the Horizontal Axis.

Type 175 Transistor-Curve Tracer High-Current Adapter $1425

HIGH-VOLTAGE TYPE 575

Supplied on order from your Tektronix Field Engineer is a special model of the Type 575 Transistor-Curve Tracer. Although similar to the Type 575, the special model provides much higher diode breakdown test voltage (*variable from zero to 1500 volts* at a maximum current of 1 milliampere) and also much higher Collector Supply (*up to 400 volts*, at 0.5 ampere).

For complete specifications of this special model—call your Tektronix Field Engineer.

Type 575 Mod 122C $1175

(prices f.o.b. factory)

. . . for more information about evaluating semiconductor devices with a Type 575 or other Tektronix test equipment, call your Tektronix Field Engineer. He will be glad to assist you.

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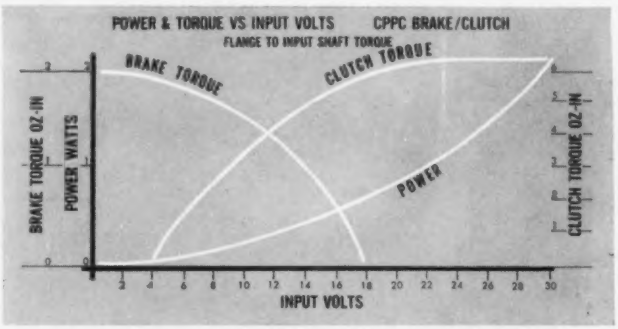
Disengaged (Maximum)	0.05 Ounce Inches
Brake	
Brake Torque (Minimum)	2.0 Ounce Inches
Polar Moment of Inertia	
Engaged	1.13 gm-cm²
Disengaged	0.78 gm-cm²
Backlash—Engaged	0 Minutes of Arc
Temperature Rise at 25° C	30° C



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